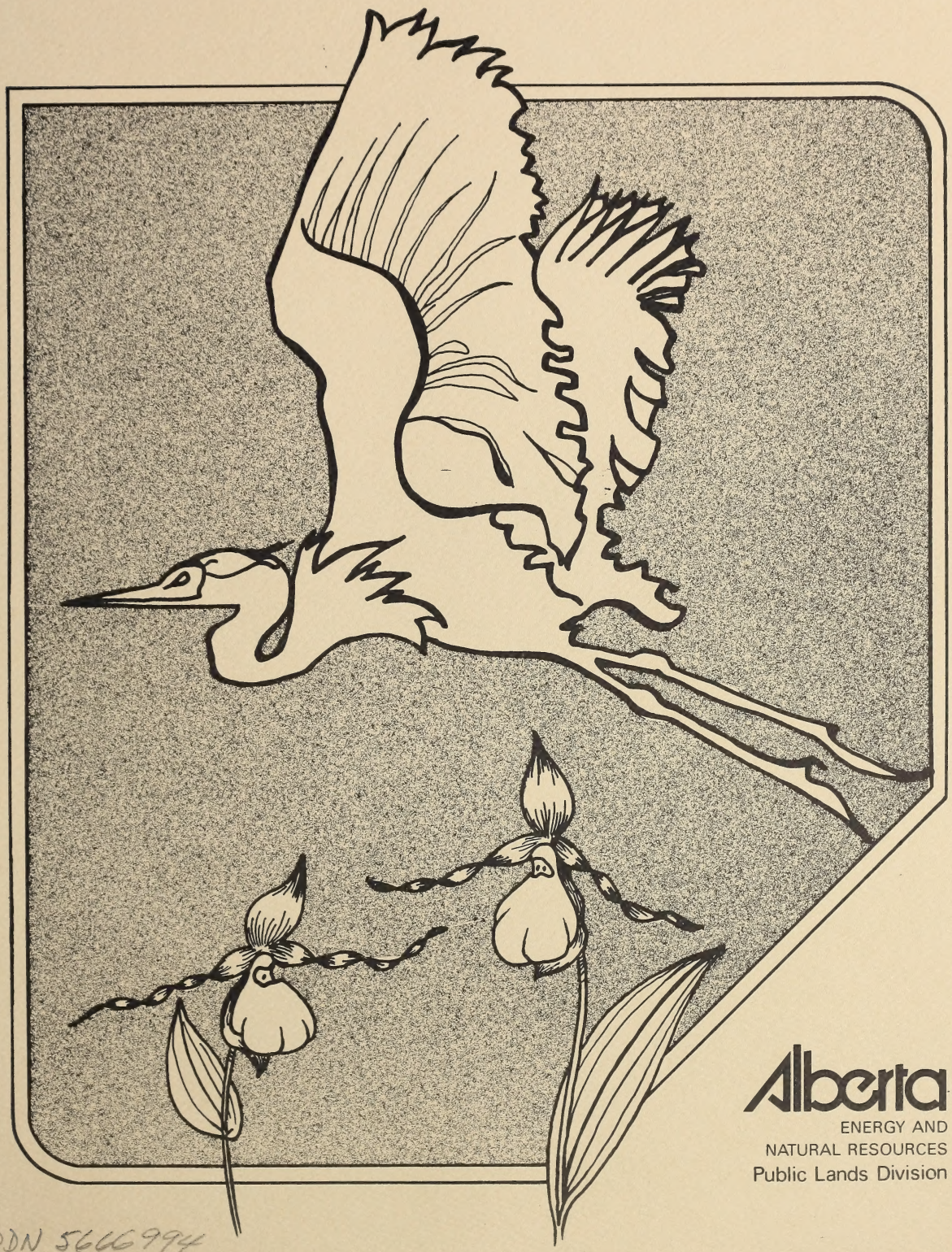
CARDINAL DIVIDE AREA
Resource Description and Comparison With Other Rocky Mountain Areas



Alberta
ENERGY AND
NATURAL RESOURCES
Public Lands Division

CARDINAL DIVIDE AREA

Resource Description and Comparison with
Other Rocky Mountain Areas

Prepared for
Natural Areas Program
Alberta Energy and Natural Resources

by

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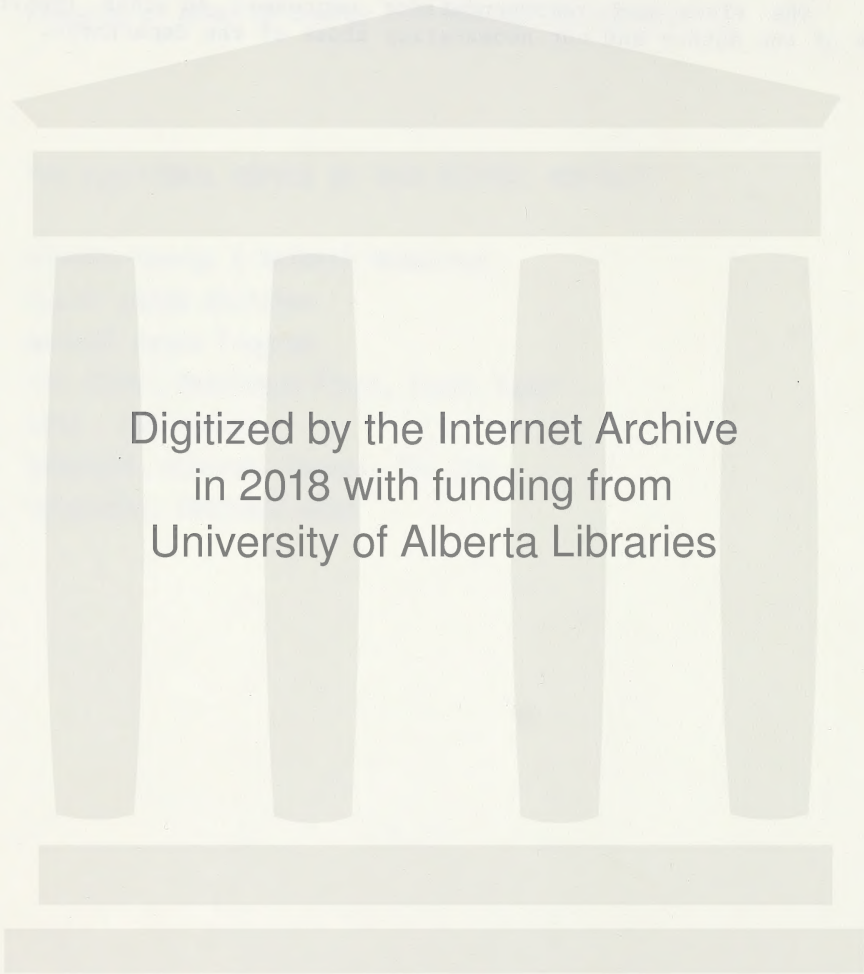
PLEASE NOTE

The views and recommendations expressed in this report are those of the author and not necessarily those of the department.



EXECUTIVE SUMMARY

A comparative study of the Cardinal Divide area was undertaken to assess the role of the Cardinal Divide area in a provincial system of conserved areas and to avoid unnecessary duplication of features already conserved in other designated areas. The natural resources of the Cardinal Divide area (climate, bedrock geology, glacial history, geomorphology, soils, flora, vegetation and animals) are described based primarily on existing literature.

The Cardinal Divide area occupies about 5763 ha (22.2 sq. mi.) in the Front Ranges of the Rocky Mountains about 70 km south of Hinton. It is currently reserved for Ecological Reserve/Wilderness Area potential. The topography is mountainous and contains the headwaters of the McLeod and Cardinal rivers. The Cardinal Divide area is part of a climatic area that includes the Rocky Mountains from the southern boundary of Banff National Park north to the British Columbia border. Bedrock is from Upper Devonian to Upper Cretaceous in age with limestones, dolomites, sandstones and shales most common. The area was glaciated by Cordilleran ice during the Pleistocene but may have been unglaciated during the late Wisconsinan. The landforms are typical of a glaciated mountain landscape with consolidated bedrock, colluvium and glacial moraine most extensive. Periglacial processes have produced various patterned ground features. Three rock glaciers occur in the area, one of which appears unique in the province. A large number of waterfalls and associated features are in the upper Cardinal River valley. Soils information is very limited but *non-soil* (rocky rubble over bedrock) and Regosolic and Brunisolic soils are most common.

The vascular flora consists of 277 species, with 35 species significant because they are either rare or geographically significant, usually disjunct. The nonvascular flora (bryophytes and lichens) is too poorly known to be evaluated presently. Most of the Cardinal Divide area is in the Alpine Ecoregion with a small portion in the Subalpine Ecoregion. Twenty-five vegetation types are recognized in the Cardinal Divide area, three of which have not been reported elsewhere in Alberta. Approximately 129 bird species and 47 mammal species have been reported for the Cardinal Divide area. The animal species diversity is high for such a small area.

Substantial evidence from several different scientific disciplines (botany, entomology and geology) suggest that the Cardinal Divide area may have been an ice-free, glacial refugium during the late Wisconsinan part of the Pleistocene ice age. The existence of an ice-free corridor

along the Front Ranges has been suggested and the Cardinal Divide area may have been part of it. More detailed studies are needed on this matter.

The Cardinal Divide area was compared with the following areas in the Rocky Mountains: Kakwa, Willmore Wilderness Park, Banff and Jasper National Parks, Ram Mountain, White Goat Wilderness Area, Siffleur Wilderness Area, Ghost River Wilderness Area, Kananaskis, Plateau Mountain, Beehive and Waterton Lakes National Park. The comparisons were hampered by a lack of comparable information between areas. Overall, the Cardinal Divide area is most similar to Banff and Jasper National Parks and probably to the White Goat Wilderness Area, although substantial differences exist among them. The areas south of about 50°N, especially Waterton Lakes National Park, are most dissimilar due to differences in climate, flora and vegetation.

Additional investigations of the Alpine Ecoregion need to be done both in the Cardinal Divide area and in other Front Range areas. No changes in the current boundary of the Cardinal Divide area is recommended at the present time. Measures need to be taken to control OHV use of the Cardinal Divide area which is currently abusing sensitive soils, vegetation and, perhaps, wildlife. The Cardinal Divide area should be retained as part of a provincial system of conserved areas due to its unduplicated constellation of representative and special features. Status as an Ecological Reserve might be most appropriate in view of its use in past and current scientific research and educational activities.

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PREFACE

The help of Natural Areas Program personnel D. Griffin, P. Lee, L. Allen and P. McIsaac on this project is appreciated. Special thanks are due J.R. Salt for sharing his knowledge of the Cardinal Divide area and making available unpublished data. Discussions with G. Ball, J.G. Packer and D.H. Vitt are gratefully acknowledged.

The views and recommendations expressed in this report are those of the author and not necessarily those of Alberta Energy and Natural Resources.

1. INTRODUCTION

This report was prepared under a contract with the Natural Areas Program of Alberta Energy and Natural Resources. The Natural Areas Program has been involved in developing a system of Natural Areas and Ecological Reserves to conserve examples of Alberta's natural environmental diversity, including both representative, typical and special or unusual features. The Cardinal Divide area has been proposed to conserve features primarily of the Alpine Ecoregion (= Alpine Biogeographic Zone) in the Northern Front Ranges of the Rocky Mountains. To avoid unnecessary duplication of features already conserved in other designated areas, a comparative study of the Cardinal Divide area was undertaken.

The terms of reference for the study can be summarized as:

1. Identify and describe special and representative features of the Cardinal Divide area.
2. Compare the Cardinal Divide area with the following areas:
    - Kakwa
    - Willmore Wilderness Park
    - Banff and Jasper National Parks
    - Ram Mountain
    - White Goat Wilderness Area
    - Siffleur Wilderness Area
    - Ghost River Wilderness Area
    - Kananaskis
    - Plateau Mountain
    - Beehive
    - Waterton Lakes National Park
3. Provide a summary evaluation of the role of the Cardinal Divide area in a provincial system of conserved areas.
4. Make appropriate changes to the special features map for the Cardinal Divide area, which is on file with the Natural Areas Program.
5. Make recommendations regarding any needed changes in the boundary of the Cardinal Divide area.

6. Make recommendations regarding further investigations of the Alpine Ecoregion in Alberta.

The features described and compared were climate, bedrock geology, glacial history, geomorphology, soils, flora, vegetation and animals. As defined in the terms of reference of this contract, *special features* include "excellent or 'classic' examples of geomorphic features or vegetation types, rare or unusual physical or biological features, areas of exceptional biophysical diversity, important faunal habitats and areas particularly sensitive to disturbance."

Information for this report is drawn primarily from existing literature. Very little field time was available for the Cardinal Divide area and none was available for the other areas. There are significant gaps in the current information as to particular features and areas which make both the description and comparative evaluation of areas difficult. Thus, many of the conclusions made here are tentative. However, the information gaps have been identified and will be hopefully filled in the near future to permit a more definitive description and evaluation.

2. NATURAL RESOURCES OF THE CARDINAL DIVIDE AREA

2.1 Location, Topography and Land Status

Location

The Cardinal Divide area occupies about 5763 ha (22.2 sq. mi.) in the Front Ranges of the Rocky Mountains in west central Alberta (Fig. 1) between about 52° 52' and 52° 58' N, and 117° 15' and 117° 30' W. The area is about 70 km south of Hinton and access is possible from the Grave Flats Forestry Road which borders the southeast portion of the area. Jasper National Park borders the area to the west. The southern part of the area is in the Rocky-Clearwater Forest while the northern part is in the Edson Forest.

Topography

The Cardinal Divide area is mountainous with relief ranging from 2755 m at the top of Prospect Mountain to about 1840 m in the valley of the west fork of Drummond Creek. The western boundary of the area is a mountainous ridge of the Miette Range which separates the drainage of the Rocky River to the west in Jasper National Park from the McLeod River and Cardinal River drainages to the east.

The Prospect Mountain ridge divides the area roughly in half. The northern half contains some of the headwaters of Harlequin Creek and Drummond Creek which flow into Whitehorse Creek and subsequently the McLeod-Athabasca system which is part of the Arctic Ocean drainage. South of the Prospect Mountain ridge are the headwaters of the Cardinal River which flows into the Brazeau-North Saskatchewan river system and eventually into Hudson's Bay. Prospect, Cheviot and Thornton creeks all originate on the northeastern slopes of the Prospect-Cheviot-Tripoli ridge and flow into the McLeod River. Several small, unnamed glacial tarns also occur in the headwaters areas of both major drainages.

The Cardinal River flows in a large, U-shaped valley which has been partially formed by former glaciers advancing from cirques at the head of the valley. The smaller valleys of Harlequin and Drummond creeks have also been modified by glacial ice originating from cirques in their upper reaches.

Fig. 1. Location of the Cardinal Divide area.

R.24

R.23

Tp. 46

Tp. 45

JASPER

NATIONAL

PARK

Whitehorse Creek

Harlequin Creek

Drummond Creek

McLeod River

Cadomin Mountain

Little Mackenzie Creek

Prospect Mountain

Chevron Mtn

Tripoli Mountain

Blackface Mtn

Cumax Mtn

Abandoned

Abandoned

Chevron Creek

Khoran Creek

Cardinal River

Divide

Figure 1.
Location of the Cardinal Divide Area
Study Area

WEST OF THE FIFTH MERIDIAN

SCALE 1:50 000

1 0 1 2 Kilometres

½ 0 ½ 1 Mile

PREPARED BY CARTOGRAPHIC SERVICES E.N.R. 1984

Land Status

The Cardinal Divide area comprises the following lands all of which are covered by a Protective Notation (PNT-760047: Ecological Reserve/Wilderness Area potential) under the Public Lands Act:

45-23-W5: NW15, N16, N17, N18, 19, S20, S21 (s/rd), SW22 (s/rd), 30

45-24-W5: N13, NE14, 22-28, 33 (all outside Jasper N.P.)

46-24-W5: 4, 5, 7-9, 16-18 (all outside Jasper N.P.)

46-25-W5: NE12, E13 (all outside Jasper N.P.)

2.2 Climate

No climatic data are available for the Cardinal Divide area itself. However, data from locations nearby provide a good indication of the climate of the area. Grave Flats Lookout, about 25 km southeast of the area at 2075 m, provides data for the months of June-August only, while year-round data for 1915-1924 are available from Mountain Park, about 4 km northeast of the area at 1780 m.

Differences in elevation and period of record complicate comparisons between the Grave Flats Lookout data (Table 1) and Mountain Park data (Table 2). The mean daily temperature for June, July and August at Mountain Park is 9°C *vs.* 8.2, 8.6 or 8.7 °C at Grave Flats Lookout, depending on the period of record. Mean total precipitation for Mountain Park is 231 mm *vs.* 256.4, 263 or 271 mm for Grave Flats Lookout, again depending on the period of record. Thus, the Cardinal Divide area is probably somewhat cooler and moister than Mountain Park, as would be expected from the higher elevation of the Cardinal Divide area. July is the warmest month with a mean temperature of about 10°C and January the coldest at about -17°C. The mean annual temperature is about -2°C. Mean annual preciptation is around 700 mm, with some 255-270 mm in June, July and August. Potential evapotranspiration is 187-199 mm which results in a water balance of +72-76 mm for June, July and August (Table 1). Degree days, using 0°C as a base, are 793-843 (Table 1). Data from the different periods of record suggest a trend of cooler, moister climate since 1941.

Table 1. Summer climatic normals for Grave Flats Lookout. Data from Environment Canada (1975a,b; 1982a,b,c) and La Roi and Ellis (1984). PET = potential evapotranspiration (Thornethwaite and Mather 1957). Water balance = mean total precipitation - potential evapotranspiration.

	1941-1970	1974-1978	1951-1980
Mean daily temperature (°C)			
June	6.7	10.1	6.8
July	10.1	13.3	9.8
August	9.4	12.0	9.1
summer $\bar{x}$	8.7	8.2	8.6
Degree days (>0°C)			
June	—	—	208.4
July	—	—	305.3
August	—	—	279.6
total	843	—	793.3
Mean total precipitation (mm)			
June	80.5	56	84.4
July	109.7	96	97.0
August	80.8	111	75.0
total	271.0	263	256.4
PET (mm)	199	187	—
Water balance (mm)	+72	+76	—

Table 2. Climatic data for Mountain Park, 1915-1924 (Russell 1980).

	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Mean daily temp. (°C)	-17	-13	-7	-2	3	7	10	10	5	1	-6	-15
Mean total precip. (mm)	87	38	49	90	77	88	65	78	45	50	23	12

Mean annual temperature = -2°C
Mean annual precipitation = 702 mm
Mean summer (J,J,A) temperature = 9°C
Mean summer (J,J,A) precipitation = 231 mm

In the Koeppen climatic classification (Koeppen 1931) the lower part of the Cardinal Divide area is Dfc (subarctic, humid, microthermal) while the upper part is ET (tundra). Powell (1978), in a climatic classification of the Prairie provinces, places the Cardinal Divide area in climatic group 10 which includes the Rocky Mountains in Alberta from approximately the

southern boundary of Banff National Park north to the British Columbia border.

In a summary of the summer climate of 14 fire lookouts in western Alberta (La Roi and Ellis 1984), Grave Flats Lookout had the lowest mean daily temperature (8.2°C), the lowest mean daily maximum temperature (14.1°C), the smallest mean daily temperature range (8.1°C), and the least summer potential evapotranspiration (187 mm). Graves Flat Lookout was placed in the cold, mesic category of a hygro-thermal, summer climate classification. This category has cold summers (<900 degree days of heat) and water balances between 0 and +80 mm. Other lookouts in this class are all near timberline in the Rocky Mountains and most are also in Powell's (1978) group 10.

2.3 Geology

Bedrock Geology

In the Cardinal Divide area, bedrock is composed mainly of limestones, dolomites, sandstones and shales with lesser amounts of siltstones and conglomerates. Bedrock age (Fig. 2) is from Upper Devonian (Fairholme Group) to Upper Cretaceous (Alberta Group). Typically, massive Palliser Formation limestones and dolomites of Upper Devonian age occur at the highest elevations along with dolomites, limestones and shales of the Fairholme Group. The McConnell thrust fault (Mountjoy 1962) separates these Paleozoic rocks from Mesozoic ones beneath. Below the fault occurs the late Jurassic to early Cretaceous Nikanassin Formation composed of sandstones and shales. Lower yet are the Cadomin, Luscar and Mountain Park Formations composed of sandstones, shales and some conglomerates forming part of the Lower Cretaceous Blairmore Group. Coal beds also occur in the Luscar Formation and have been mined commercially at Mountain Park. Small amounts of the Blackstone, Cardium and Wapiabi Formations, part of the Upper Cretaceous Alberta Group, also occur in the area as shales, sandstones and siltstones.

Differences in resistance to erosion of different bedrock contribute to relief in the area. More resistant limestones and dolomites typically form ridges and mountain tops while less resistant sandstones and shales form slopes and valleys.

ERA	PERIOD		GROUP	FORMATION
Mesozoic	Cretaceous	Upper	Alberta	Wapiabi Cardium Blackstone
		Lower	Blairmore	Mountain Park Luscar Cadomin
				Nikanassin
	Jurassic		Fernie	
	Triassic			Whitehorse
Paleozoic	Mississippian		Rundle	
				Banff
	Devonian	Upper		Palliser
			Fairholme	

Fig. 2. GENERALIZED BEDROCK STRATIGRAPHIC COLUMN FOR CARDINAL DIVIDE AREA.

Further detail on bedrock geology is in Mackay (1929), Mountjoy (1961, 1962), Irish (1965), Stott (1963), Mellon (1966), Price and Mountjoy (1970), Holter and Mellon (1972), Holter and McLaws (1977) and Kilby (1978).

Glacial History

The Cardinal Divide area was apparently glaciated only by Cordilleran ice during the Pleistocene (Williams and Bayrock 1966, Reimchen and Bayrock 1977). Laurentide ice approached the area from the northeast, probably in the early Wisconsinan, but coalesced with eastward moving Cordilleran ice east of the Cardinal Divide area and then flowed southeastward (Roed 1968).

The earliest record of glaciation in the Cardinal Divide area is pre-Wisconsinan, probably Illinoisan (Bayrock 1969). These glaciers were part of a large ice sheet which covered all of the Rocky Mountains and foothills leaving tills over most of the landscape (Reimchen and Bayrock 1977). Early Wisconsinan (>35,000 years BP, Bayrock 1969) glaciers in the area were part of a reticulate ice sheet which covered most of the Rocky Mountains leaving only a few nunataks exposed (Reimchen and Bayrock 1977). Late Wisconsinan glaciers appear to have been large valley glaciers which flowed into piedmont-type glaciers in the Athabasca and North Saskatchewan river valleys.

The extent of ice-free area during the late Wisconsinan is important to considerations of the Cardinal Divide area as a glacial refugium during that time. Reimchen and Bayrock (1977) state that during the late Wisconsinan "over 90% of the area between major mountain valleys in the Rocky Mountains and Foothills was ice-free." Reeves (1973) suggests that large areas of the Front Ranges "above and adjacent to valley and piedmont glaciers were ice-free" during this time. These may have been part of a series of disjunct ice-free areas, or perhaps an ice-free corrider, that existed between the Cordilleran and Laurentide ice masses for much of the Wisconsinan.

How these generalized accounts apply to the Cardinal Divide area specifically is less clear. Reimchen and Bayrock (1977) indicate the maximum altitude of the ice during the Wisconsinan to be about 2600 m. Their map of surficial deposits in the Cardinal Divide area shows the upper altitude of late Wisconsinan till to be approximately 2100 m. Materials above this are shown mostly as colluvial deposits which are post-glacial and thus, have buried the upper portion of

the late Wisconsinan till. Consequently, the extent to which the Cardinal Divide area was ice-free during the late Wisconsinan is not clear from current information.

The most recent glacial tills in the Cardinal Divide area were deposited by relatively small cirque glaciers probably since the Altithermal (*ca.* 6000 years BP, Reimchen and Bayrock 1977). These tills have been identified at the head of Drummond Creek, along the Cardinal River and northeast of the Tripoli Mountain ridge.

Deglaciation of western Alberta began by about 12,000-14,000 years BP and recession of Cordilleran ice from the eastern edge of the mountains began by at least 11,500 years BP (Glover 1979). Major valleys were ice-free by about 10,500 years BP (Reeves 1973) and thus most of the Cardinal Divide area was probably also ice-free soon thereafter, if indeed it had not been ice-free earlier.

2.4 Geomorphology

Landforms

The landform classification used here is that of the Canada Soil Survey Committee (1978) which is based on genetic material and form or surface expression. Three genetic material components occur in the Cardinal Divide area: *consolidated mineral, unconsolidated mineral* and *organic*.

The *consolidated mineral* component consists of tightly packed bedrock, both weathered and unweathered. Bedrock underlies the entire area and outcrops most commonly at high elevations where it forms mountain and ridge tops. Bedrock outcrops have usually been frost shattered producing a rocky, uneven surface.

The *unconsolidated mineral* component is divided into classes based on mode of origin. Colluvial material has been deposited by gravity, including both slow movement, such as slope creep and faster events such as landslides, rockfalls and avalanches. Colluvium occurs mainly on steep, upper slopes below bedrock cliffs in the form of veneers, blankets, fans or aprons over bedrock. A more localized colluvial feature has been formed in the Cardinal River valley near the southwest corner of the area by a rotational slump. Snow avalanches occur on many colluvial slopes but are not easy to identify from summer conditions since most of the vegetation

of the area is little affected by avalanches. Only some communities containing trees or tall shrubs show prominent evidence of avalanche activity. Examination of late winter or early spring snow surfaces would best indicate avalanche occurrence.

Morainal material or till has been deposited by glacial ice. Moraine is widespread in the area occurring on lower slopes, valley bottoms and benchlands. Surface form includes veneers and blankets usually deposited as ground moraine over bedrock as well as hummocky or ridged moraine deposited as a lateral or terminal moraine or perhaps due to ridged bedrock beneath.

Fluvial materials have been deposited by flowing water and occur in the area as small fans and terraces along the Cardinal River, Harlequin and Drummond creeks. In some areas, especially along lower slopes, shallow veneers of fluvial material occur due mostly to localized slope wash. Glaciofluvial material is closely related in origin to fluvial material but has not been recognized in the Cardinal Divide area to date.

Eolian material has been deposited by wind. In the Cardinal Divide area it is probably a mixture of volcanic ash (Dumanski *et al.* 1980) and more locally derived loess. Eolian material occurs commonly as a veneer over much of the morainal deposits in the area.

The *organic component* consists of peat deposits in the form of level or gently sloping fens at the toe of fluvial fans. Organic landforms are neither common nor extensive in the area.

Periglacial Features

Periglacial features are produced by nonglacial processes operating in cold climates (Washburn 1973). In the Cardinal Divide area these processes include frost action (frost cracking, heaving, sorting and creep) and gelifluction (solifluction associated with frozen ground). The features produced are collectively termed *patterned ground* and are due primarily to intensive frost action. The form of the features is affected by the slope angle. On level to gently sloping areas, nonsorted circles and polygons (Washburn 1973) occur. Moderately sloping sites have nonsorted steps or terraces (sometimes termed gelifluction or solifluction terraces or lobes) produced by a combination of frost action and gelifluction. Steeply sloping sites have both sorted and nonsorted stripes which are oriented perpendicular to the contour. On yet steeper slopes, the vegetated stripes break up into vegetated islands or *spotted tundra* (Bamberg and Major 1968). The steepest sites are occupied by scree slopes in which no patterning is apparent,

although processes such as frost creep and gelifluction are still operating.

Nivation hollows also occur. These have formed beneath shallow snowbanks by localized erosion due to frost action, gelifluction and water erosion.

At least three rock glaciers occur in the Cardinal Divide area; two in the upper part of the west fork of Drummond Creek (SW8-46-24-W5 and SW9-46-24-W5) and the other near the head of the main part of Drummond Creek (NE33-45-24-W5). Rock glaciers are common in the Rocky Mountains, although more so in the Main Ranges than in the Front Ranges (Luckman and Crockett 1978). The rock glacier in SW8 has been examined on the ground while the other two have only been noted on air photos. The one in SW8 is ice-cored and tongue-shaped (Crockett 1981). Rock glaciers most typically are formed of coarse, blocky material and are little vegetated due largely to lack of fine soil material. The detritus forming this one contains a high shale content which has weathered to a fine-textured soil. Thus, the rock glacier is nearly entirely vegetated which is a rare occurrence. There is also some evidence of recent activity in the form of unvegetated, freshly exposed faces. although the evidence is not conclusive. This rock glacier is not typical of those in the Front Ranges (Crockett 1981). Its fine texture, mostly vegetated condition and low altitude (2120-2270 m) are probably unique in the province. Active or recently active rock glaciers are also very rare in the Rocky Mountains.

Waterfalls

The upper part of the Cardinal River contains a large number of waterfalls, cascades, potholes and glen-like features. They have been formed by differential water erosion across various bedrock layers. These features are not large, relief is generally not more than 10 m, but the number and variety is notable.

2.5 Soils

The soil classification used here is that of the Canada Soil Survey Committee (1978). No soil survey has been done in the Cardinal Divide area. The closest is just north of the area (Dumanski *et al.* 1972) but it does not deal with the mountainous parts. Thus, the following is based on the author's observations in the area, the author's experience in adjacent parts of Jasper National Park (Holland and Coen 1982) and the results of Mortimer (1978) on Prospect

Mountain.

Much of the Cardinal Divide area, especially at higher elevations, is covered by *nonsoil*, that is <10 cm of unconsolidated material over bedrock. Elsewhere, soils of the Regosolic and Brunisolic Orders are most common, and small amounts of Gleysolics and Organics also occur.

Regosolics occur typically on sites which are active geomorphically such that horizon development has been minimal. These often include colluvial slopes and sites of fluvial deposition. Orthic Regosols are common under *Dryas* spp. mats, while Orthic Humic Regosols with thicker surficial humus-rich layers occur on more densely vegetated sites. Where periodic disturbances such as cryoturbation or solifluction occur, the soils are often Cumulic Regosols or Cumulic Humic Regosols. Lithic and turbic phases of the above soils are common in the area.

Brunisolic soils occur typically on more stable sites. Because of the large amount of calcareous bedrock in the area the Eutric and Melanic Great Groups (pH >5.5) are most common although locally, Dystric and Sombric Brunisols (pH <5.5) have developed on noncalcareous parent materials. Orthic Eutric Brunisols and Orthic Melanic Brunisols are most frequent, the latter having thicker (>10 cm) surficial humus-rich layers. Lithic and turbic phases are common. Brunisolic soils occur on many landforms but are perhaps most common on moraine and colluvium.

Rego Gleysols and Terric Mesisols occur on the wettest, most poorly drained sites usually on fluvial landforms and in association with sedge fen or shrub vegetation. Such sites occupy a very small part of the area.

2.6 Flora

The *flora* of an area is a list of the plant species which occur there. *Vegetation*, on the other hand, consists of a quantitative description of the plant communities of an area, their composition, structure, cover, biomass, *etc.* Accounts of both are needed to describe the botanical features of an area.

Vascular plants are mainly considered here since, with a few exceptions, the nonvasculars (bryophytes and lichens) are too poorly known to make a meaningful evaluation. Various

people have collected vascular plants in the Cardinal Divide area and this information has been summarized in a list (Natural Areas Program 1983). There are nomenclatural and taxonomic inconsistencies in the list. Most have been resolved using Packer (1983) and a revised list of the vascular flora is in Appendix 1. It should be emphasized that the list is only preliminary and that more intensive collecting will likely discover additional species. The nonvasculars collected to date are listed in Appendix 2.

The currently known vascular flora of the Cardinal Divide area comprises 277 species. Of these, 35 or about 12% of the flora are significant because they are either rare (Packer and Bradley 1984) or geographically significant, usually disjunct (Packer and Vitt 1974, Mortimer 1978). The species and the reason for their significance are listed below.

Androsace chamaejasme - disjunct
Antennaria monocephala - disjunct
Arnica louiseana - disjunct
Artemisia borealis - rare and disjunct
Braya purpurascens - rare and disjunct
Campanula uniflora - disjunct
Carex franklinii - rare
Carex misandra - rare and disjunct
Carex paysonis - rare
Carex petricosa - disjunct
Claytonia megarhiza - at northern range boundary
Draba fladnizensis - rare
Draba macounii - disjunct
Epilobium saximontanum - rare
Erigeron radicatus - rare and disjunct
Eriophorum callitrix - rare and disjunct
Hierochloe alpina - rare
Kobresia simpliciuscula - disjunct
Lesquerella arctica - rare and disjunct
Oxytropis jordalii - rare and disjunct
Papaver kluanensis - disjunct

Pedicularis flammea - disjunct

Pedicularis lanata - rare

Polemonium viscosum - rare and disjunct

Potentilla villosa - rare

Pyrola grandiflora - disjunct

Rhododendron lapponicum - rare and disjunct

Rumex acetosa ssp. *alpestris* - disjunct

Salix alaxensis - rare and disjunct

Salix reticulata ssp. *reticulata* - rare and disjunct

Saxifraga flagellaris - disjunct

Saxifraga nivalis - rare

Selaginella rupestris - rare

Smelowskia calycina - disjunct

Telesonix heucheriformis - rare and disjunct

The implications of the occurrence of these rare and disjunct species for a glacial refugium hypothesis are discussed below (section 2.9). However, whether the refugium hypothesis is ultimately accepted or rejected, the number of significant species which occur in the Cardinal Divide area is notable and makes the area valuable.

Also of interest are two cases of apparent hybridization. Both *Dryas octopetala* ssp. *hookeriana* and *Dryas integrifolia* are present and are hybridizing, judging from the prevalence of intermediate forms. These two species appear to hybridize in other locations as well and more details are in Crack (1977) and Mortimer (1978). In the genus *Phyllodoce*, the two parent species, *Phyllodoce glanduliflora* and *P. empetriformis*, and their hybrid, *P. x intermedia*, also occur. The wide range of variability in the hybrids in both cases suggests that introgressive hybridization is occurring.

2.7 Vegetation

The Cardinal Divide area contains portions of the Alpine and Subalpine Ecoregions (Pettapiece *et al.* 1980). Most of the area is in the Alpine Ecoregion which is treeless and occurs above about 2200 m. Vegetated parts of the Alpine are characterized by a complex, fine-scaled mosaic of tundra plant communities in which microclimatic variations are reflected in marked changes in community types. Significant microclimatic factors include slope, aspect, snow depth and duration, wind and soil moisture. Much of the Alpine in the area is colluvial talus and frost-shattered bedrock with little or no vegetation.

The Subalpine Ecoregion occurs below the Alpine Ecoregion. The Subalpine is often divided into Upper Subalpine and Lower Subalpine portions (Achuff and Corns 1982). Lower Subalpine is characterized by coniferous closed forests and occurs outside the Cardinal Divide area at lower elevations. Thus, the Subalpine in the Cardinal Divide area is Upper Subalpine. Upper Subalpine is broadly transitional between Lower Subalpine closed forests and treeless Alpine tundra. The vegetation characteristically consists of open forests and stunted trees (*Krummholz*). Some closed forests occur in the Upper Subalpine but usually contain Alpine species in the understory. *Picea engelmannii* and *Abies lasiocarpa* are characteristic dominant trees and *Pinus contorta* is usually absent.

Several workers have described the plant communities of various parts of the Cardinal Divide area using a variety of methods. The following descriptions of vegetation types are based on the data from Prospect Mountain of Mortimer (1978) and See and Bliss (1980), as well as data from throughout the area of the Alberta Ecological Survey (1975), Natural Areas Program (1980-1982) and the author's field notes (1974-1984). Judgement as to what constitutes a valid vegetation type and what is only a minor variant or heterogeneous is based on the author's experience both in the Cardinal Divide area and in other parts of the Rocky Mountains. This procedure may overlook small or infrequent vegetation types but, given current information, it provides recognition of fairly uniform vegetation types at a scale comparable to that of studies of other Front Range areas (*e.g.* Achuff and Corns 1982, Lee *et al.* 1982).

Twenty-five vegetation types were recognized for the Cardinal Divide area. The vegetation types were classified initially by structure or physiognomy into five classes: *Closed Forest, Open Forest, Shrub, Low Shrub-Herb,* and *Herb-Dwarf Shrub.* In *Closed Forest*, the distance between

tree crowns is no more than twice the mean crown diameter. This generally corresponds to a lower limit of 15 to 20% tree cover. In *Open Forest*, the distance between crowns is 2X to 5X mean crown diameter and tree cover is generally between 5% and 15 to 20%. Vegetation with <5% tree cover is not considered forested. *Shrub* vegetation is dominated by woody plants 1 to 5 m tall, *Low Shrub-Herb* vegetation is dominated by woody plants 0.5 to 1 m tall and herbs, and *Herb-Dwarf Shrub* vegetation is dominated by woody plants <0.5 m tall or herbs. Within these structural classes, the classification is based primarily on species dominance in each layer and on characteristic combinations of species. Dominance or importance is based on cover values and thus, the classification has a quantitative basis.

In the descriptions below, each vegetation type is given a name based on the scientific (Latin) name of the dominant or characteristic species as well as one based on the common names of the dominant or characteristic species. Most of the vegetation types in the Cardinal Divide area are referable to vegetation types recognized in Banff and Jasper National Parks (Achuff and Corns 1982). The vegetation type names from the Banff-Jasper system are used here because that system covers the majority of the Rocky Mountains in Alberta and the author has found the vegetation types of this system to occur in much of the rest of the Rocky Mountains in Alberta (*e.g.* Willmore Wilderness Park, White Goat and Siffleur Wilderness Areas, Beehive). Also, development of the Banff-Jasper system included a thorough literature review and thus, through a synthesis of vegetation classification information, it provides a preliminary basis for a uniform classification and nomenclature of Rocky Mountain vegetation.

This results in some apparent anomalies. For example, an *Elymus innovatus-Koeleria cristata-Arctostaphylos uva-ursi* type is described but to date no *Koeleria cristata* has been collected in the Cardinal Divide area. *Koeleria cristata* occurs all around the Cardinal Divide area and with more intensive collecting will probably be found in the area. Since these grasslands in the Cardinal Divide area fit the concept of this vegetation type in every way except the presence of *Koeleria cristata*, they are referred to this type at present.

Each vegetation type is described in terms of its location and environmental situation in the Cardinal Divide area, and the dominant or characteristic species of each layer are listed. In vegetation type names, a hyphen (-) separates species in the same layer and a virgule (/) separates layers.

Three of the vegetation types described below appear to be unique to the Cardinal Divide area: 11. *Salix drummondiana-Thalictrum venulosum*, 23. *Artemisia norvegica-Mertensia paniculata--Elymus innovatus*, and 24. *Antennaria lanata-Artemisia norvegica*. The first occurs in the Harlequin and Drummond creek valleys. The latter two occur in the Harlequin Creek valley and are notable by the large amount of *Artemisia norvegica* and *Mertensia paniculata* which they contain. Similar communities may occur in the Willmore Wilderness Park but the vegetation of the Willmore is too poorly known at present to make a definite determination. The other vegetation types occur in other areas of the Rocky Mountains to varying degrees (Table 3).

Vegetation Types

Closed Forest Vegetation Types

1. *Picea engelmannii-Abies lasiocarpa/Phyllodoce glanduliflora/Hylocomium splendens* (Engelmann spruce-subalpine fir/heather/feathermoss)

This vegetation type occurs on mesic, Upper Subalpine sites in the Drummond Creek and Cardinal River valleys. It was likely more extensive in Drummond Creek valley and on Prospect Mountain before part of the area was burned, probably in 1913. It occurs mainly on morainal landforms and the soils are mostly Brunisolics.

The tree layer is closed and dominated by *Picea engelmannii* and *Abies lasiocarpa*. Regeneration of these two trees forms most of the shrub layer. The understory is dominated by *Phyllodoce glanduliflora* with *Vaccinium scoparium* and *Cassiope* spp. also often important. The moss layer is dominated by the feathermosses *Hylocomium splendens, Pleurozium schreberi* and *Ptilium crista-castrensis*.

Open Forest Vegetation Types

2. *Picea engelmannii-Abies lasiocarpa/Valeriana sitchensis-Erigeron peregrinus* (Engelmann spruce-subalpine fir/valerian-fleabane)

This open forest type occurs on mesic to subhygric sites in lower slope positions of the Upper Subalpine in Drummond Creek valley and probably along Cheviot and Thornton creeks. The

Table 3. Occurrence of vegetation types of the Cardinal Divide area in other Rocky Mountain areas. Areas are: **KW** - Kakwa, **WW** - Willmore Wilderness Park, **BJ** - Banff and Jasper National Parks, **RM** - Ram Mountain, **WG** - White Goat Wilderness Area, **SF** - Siffleur Wilderness Area, **GR** - Ghost River Wilderness Area, **KN** - Kananaskis, **PM** - Plateau Mountain, **BH** - Beehive, **WL** - Waterton Lakes National Park.

	Other Rocky Mountain Areas										
	KW	WW	BJ	RM	WG	SF	GR	KN	PM	BH	WL
Closed Forest											
1. spruce-fir/heather/feathermoss	+	−	+	−	+	+	−	−	−	−	−
Open Forest											
2. spruce-fir/valerian-fleabane	−	+	+	−	−	+	−	−	−	−	−
3. spruce-fir/heather	+	+	+	+	+	+	+	+	−	−	−
4. spruce-fir/willow/lousewort	−	+	+	−	−	+	−	+	−	−	−
5. spruce-fir/avens	−	−	+	+	−	−	−	−	+	−	−
Shrub											
6. fir-willow	−	−	+	−	+	−	−	−	−	−	−
7. birch-cinquefoil/needlerush	−	−	+	−	+	−	−	−	−	−	−
8. willow-cinquefoil	+	+	+	−	+	+	−	+	−	+	−
9. willow-birch-cinquefoil	−	−	+	−	+	−	−	−	−	−	−
10. willow-wild rye	−	+	+	−	+	+	−	−	−	−	−
11. willow-meadow rue	−	−	−	−	−	−	−	−	−	−	−
Low Shrub-Herb											
12. heather-avens-willow	+	+	+	−	+	+	−	+	+	−	−
13. heather-everlasting	+	+	+	−	+	+	+	+	+	−	−
14. arctic willow-cinquefoil	+	+	+	−	+	−	−	+	−	+	−
Herb-Dwarf Shrub											
15. avens-willow-campion	+	+	+	+	+	+	+	+	+	+	+
16. avens-sedge	−	−	+	−	−	−	−	−	−	−	−
17. avens-kobresia-bearberry	+	+	+	+	+	+	+	+	+	+	+
18. wild rye-strawberry-fireweed	−	+	+	−	−	+	−	+	−	+	−
19. wild rye-junegrass-bearberry	−	+	+	−	−	−	+	+	−	−	−
20. sedge-everlasting	+	−	+	−	+	+	−	+	−	−	−
21. water sedge-beaked sedge	+	+	+	−	+	+	−	+	+	+	+
22. fleabane-valerian	+	+	+	−	−	−	−	+	−	+	+
23. wormwood-bluebell-wild rye	−	−	−	−	−	−	−	−	−	−	−
24. everlasting-wormwood	−	−	−	−	−	−	−	−	−	−	−
25. saxicolous lichen	+	+	+	−	+	+	+	+	+	+	+

landforms are morainal and fluvial. Drainage varies with seepage often present. The soils are similarly varied consisting mostly of Brunisolics.

The open tree layer is composed primarily of *Picea engelmannii* and *Abies lasiocarpa*. The shrub layer is sparse and dominated by regeneration of the two tree species. The understory is

species-rich and dominated by moist herbs including: *Valeriana sitchensis, Erigeron peregrinus, Artemisia norvegica, Trollius albiflorus, Anemone occidentalis* and *Senecio triangularis*. Few bryoids occur in this type.

3. *Picea engelmannii-Abies lasiocarpa/ Phyllodoce glandulifiora-Cassiope mertensiana*
(Engelmann spruce-subalpine fir/heather)

This is the most common open forest type in the Cardinal Divide area. It occurs throughout the area on mesic Upper Subalpine sites at treeline. The landforms are mainly morainal and the soils are typically well drained Brunisolics.

Picea engelmannii and *Abies lasiocarpa* are dominant in the open tree layer. Shrub cover is usually low and composed of tree regeneration or scattered *Salix* spp. The herb-dwarf shrub layer is dominated by *Phyllodoce glandulifiora, Phyllodoce empetriformis, Cassiope mertensiana* and *Vaccinium scoparium*. Bryoid cover varies but usually consists of both liverworts (*Barbilophozia lycopodioides*) and mosses (*Dicranum scoparium, Pleurozium schreberi, Hylocomium splendens*).

4. *Picea engelmannii-Abies lasiocarpa/ Salix vestita/ Pedicularis bracteosa*
(Engelmann spruce-subalpine fir/rock willow/bracted lousewort)

This open forest vegetation type occurs on subhygric to hygric, Upper Subalpine sites in the Cardinal River valley and east of Tripoli Mountain. The landforms are mainly morainal and the soils are typically imperfectly to poorly drained Gleysols and gleyed Brunisolics.

Picea engelmannii is dominant with *Abies lasiocarpa* usually present with low cover. The shrub layer is dense and dominated by *Salix vestita* and *Abies lasiocarpa*. The understory is composed of lush herbs such as *Pedicularis bracteosa, Erigeron peregrinus, Polygonum viviparum* and *Anemone occidentalis*. Mosses are common with *Pleurozium schreberi* and *Aulacomnium palustre* typical.

5. *Picea engelmanni-Abies lasiocarpa/ Dryas octopetala*
(Engelmann spruce-subalpine fir/mountain avens)

This vegetation type occurs on mesic Upper Subalpine sites in Drummond Creek valley. The soils are well drained Brunisolics and Regosolics developed on morainal and colluvial landforms which are often soliflucted.

The open tree layer consists of *Picea engelmannii* and *Abies lasiocarpa* which are often stunted. The sparse understory consists mostly of *Dryas octopetela*, although some *Dryas integrifolia* and *D. octopetala* X *D. integrifolia* hybrids are also often present. Other typical understory species include *Salix arctica, Arctostaphylos rubra, Artemisia norvegica* and *Carex* spp. Bryoid cover is usually low and bare soil often covers 25 to 30% of the site.

Shrub Vegetation Types

6. *Abies lasiocarpa-Salix* spp./*Valeriana sitchensis*
(subalpine fir-willow)

This Upper Subalpine shrub type occurs on steeply sloping, mesic sites in Drummond Creek valley as well as east of Tripoli Mountain. The landforms are mostly colluvial and the soils are Regosolics and Brunisolics.

Dwarfed *Abies lasiocarpa* is dominant with *Salix vestita* and *S. glauca* usually also present. The understory is dominated by moist herbs: *Valeriana sitchensis, Artemisia norvegica, Pedicularis bracteosa* and *Epilobium angustifolium*. Bryoids are sparse. Dwarfing of the shrubs appears due to avalanching or wind scour.

7. *Betula glandulosa-Potentilla fruticosa/Scirpus caespitosus/Drepanocladus revolvens*
(dwarf birch-shrubby cinquefoil/needlerush)

This Upper Subalpine type occurs on nearly level, poorly drained sites in valley bottoms along the Cardinal River and Drummond, Harlequin and Thornton creeks. The soils are Organics and Gleysolics mostly on fluvial landforms.

Shrub cover is sparse with *Betula glandulosa* and *Potentilla fruticosa* dominant. *Scirpus caespitosus* is most important in the herb layer with *Carex* spp., *Equisetum* spp. and *Pedicularis groenlandicum* also common. Moss cover is dense with *Drepanocladus revolvens, Tomenthypnum nitens* and *Aulacomnium palustre* most important.

8. *Salix barrattiana/Potentilla diversifolia*
(willow/cinquefoil)

This shrub type occurs commonly throughout the Cardinal Divide area on subhygric to hygric, Upper Subalpine sites. The landforms are mostly gently sloping fluvial or occasionally morainal deposits. Soils are usually imperfectly to poorly drained Regosols and Gleysols.

The shrub layer is dominated by *Salix barrattiana* with *Salix glauca* often present also. The understory is species-rich with *Potentilla diversifolia, Artemisia norvegica, Trollius albiflorus, Valeriana sitchensis* and *Erigeron peregrinus* most common. Bryoid cover is usually low.

9. *Salix glauca-Betula glandulosa-Potentilla fruticosa*
(willow-dwarf birch-shrubby cinquefoil)

This vegetation type occurs on mesic to subxeric, Upper Subalpine sites in the Cardinal River and Drummond Creek valleys. In some cases, the sites have been burned and the vegetation is probably seral. Landforms are mostly colluvial but some are morainal. Soils are well drained Regosolics and Brunisolics. Some of the sites may be avalanched as well.

Salix glauca is usually dominant with *Betula glandulosa* often codominant and *Potentilla fruticosa* often present with lower cover. *Juniperus communis* and other *Salix* spp. are also often present. Common herbs and dwarf shrubs include *Arctostaphylos uva-ursi, Elymus innovatus, Epilobium angustifolium, Fragaria virginiana* and *Achillea millefolium*. Bryoid cover is low with *Tortula ruralis* and *Peltigera* spp. most common.

10. *Salix glauca/Elymus innovatus*
(willow/hairy wild rye)

This vegetation type occurs throughout the Cardinal Divide area on mesic to subhygric sites in the Upper Subalpine. Soils are well to imperfectly drained Brunisolics and Regosolics on fluvial and morainal landforms.

Salix glauca is the dominant shrub with *Betula glandulosa* and other *Salix* spp. also common. *Elymus innovatus* dominates the understory. Other typical species include *Fragaria virginiana, Epilobium angustifolium, Achillea millefolium, Potentilla diversifolia* and *Delphinium glaucum*.

Bryoid cover is low.

11. *Salix drummondiana/Thalictrum venulosum*
(willow/meadow rue)

This shrub vegetation type occurs on subhygric to hygric sites in the Upper Subalpine along Harlequin and Drummond Creeks. The soils are imperfectly to poorly drained Gleysolics and Regosolics developed on fluvial landforms which border the creeks.

Salix drummondiana is the dominant shrub and *Salix barrattiana* is also common. The understory is dominated by lush herbs such as *Thalictrum venulosum, Senecio triangularis, Deschampsia caespitosa, Heracleum lanatum, Aconitum delphinifolium,* and *Erigeron peregrinus*. Bryoid cover is low.

Low Shrub-Herb Vegetation Types

12. *Cassiope tetragona-Dryas octopetala-Salix nivalis*
(white mountain heather-mountain avens-snow willow)

This type occurs on mesic to subhygric Alpine tundra sites throughout the Cardinal Divide area in fairly deep snowbeds. Soils are Brunisolics and Regosolics developed on morainal and colluvial landforms.

Cassiope tetragona is the dominant species with *Dryas octopetala* (or *Dryas integrifolia* and their hybrids) and *Salix nivalis* often codominant. Other common species include *Phyllodoce glandulifiora, Polygonum viviparum, Potentilla diversifolia* and *Salix arctica*. Bryoid cover is usually low with *Dicranum scoparium* and *Cetraria* spp. typical.

13. *Phyllodoce glandulifiora-Cassiope mertensiana-Antennaria lanata*
(heather-everlasting)

This heather tundra type occurs on mesic Alpine sites throughout the Cardinal Divide area in sites with moderately deep winter snow cover. Soils are mostly Brunisolics developed on morainal landforms which are often soliflucted.

Phyllodoce glanduliflora is usually dominant with lesser amounts of *Cassiope mertensiana* and *Antennaria lanata*. Other characteristic species are *Phyllodoce empetriformis, Cassiope tetragona, Salix arctica, Artemisia norvegica, Sibbaldia procumbens* and *Potentilla diversifolia*. Bryoid cover is usually low.

14. *Salix arctica-Potentilla diversifolia*
(arctic willow-cinquefoil)

This low shrub-herb type occurs on mesic to subhygric Upper Subalpine to Alpine sites throughout the Cardinal Divide area. Soils are well to imperfectly drained Regosolics and Brunisolics on morainal, colluvial and fluvial landforms. The sites are often soliflucted, in deep snow accumulation areas and receive seepage through much of the growing season.

This type is species-rich with *Salix arctica* dominant and *Potentilla diversifolia, Antennaria lanata, Anemone occidentalis, Artemisia norvegica, Erigeron peregrinus* and *Poa alpina* common. Bryoid cover is generally low with both lichens and mosses present. Typical species include *Cladonia pyxidata, Cetraria ericetorum, Cetraria cucullata* and *Polytrichum juniperinum*.

Herb-Dwarf Shrub Vegetation Types

15. *Dryas octopetala-Salix nivalis-Silene acaulis*
(mountain avens-snow willow-moss campion)

This type occurs on mesic to subxeric Alpine sites throughout the area. Soils are well drained Regosolics and Brunisolics on morainal and colluvial landforms. Solifluction is common.

Both *Dryas octopetala* and *Dryas integrifolia*, as well as hybrids between the two species, occur in this vegetation type and are dominant. *Salix nivalis* is often codominant. Other important species include *Silene acaulis, Potentilla diversifolia, Oxytropis podocarpa, Polygonum viviparum* and *Potentilla nivea*. Bryoid cover is low with the lichens *Cetraria nivalis, Cetraria cucullata, Cetraria ericetorum* and *Cetraria tilesii* most frequent. This type occupies wind-swept sites with low winter snow cover.

16. *Dryas integrifolia-Carex rupestris*

(mountain avens-curly sedge)

This uncommon vegetation type occurs on subhygric Upper Subalpine to Alpine sites in Harlequin Creek valley and on Prospect Mountain. Soils are mostly Regosolics on morainal and colluvial landforms.

Dryas integrifolia and *Carex rupestris* are the dominant plants. Other typical species include *Carex nardina*, *Arctostaphylos rubra*, *Saxifraga oppositifolia*, and *Oxytropis podocarpa*. Bryoid cover is low with *Cetraria tilesii* and *Cetraria cucullata* common.

17. *Dryas octopetala-Kobresia myosuroides-Arctostaphylos uva-ursi*
(mountain avens-kobresia-bearberry)

This type occurs on subxeric to mesic Upper Subalpine to Alpine sites throughout the Cardinal Divide area usually on southerly aspect slopes and ridge tops. Soils are well drained Regosolics and Brunisolics on morainal and colluvial landforms. The sites are wind-swept and have low winter snow cover.

Dryas octopetala (or *Dryas integrifolia* and their hybrids) and *Kobresia myosuroides* dominate this type. Other characteristic species include *Arctostaphylos uva-ursi, Polygonum viviparum, Oxytropis podocarpa* and *Silene acaulis*. Bryoid cover is low with lichens such as *Cetraria cucullata* and *Cetraria nivalis* frequent.

18. *Elymus innnovatus-Fragaria virginiana-Epilobium angustifolium*
(hairy wild rye-wild strawberry-fireweed)

This grassland vegetation type occurs on mesic Upper Subalpine sites in Harlequin Creek valley and on Prospect Mountain. Soils are well drained Brunisolics and Regosolics on colluvial and morainal landforms. Some of the sites appear to be snow avalanched.

Elymus innovatus is dominant with *Fragaria virginiana* and *Epilobium angustifolium* often important to codominant. Other characteristic species include *Achillea millefolium, Potentilla diversifolia, Myosotis alpestris, Heracleum lanatum* and *Zygadenus elegans*. Bryoid cover is low.

19. *Elymus innovatus-Koeleria cristata-Arctostaphylos uva-ursi*
(hairy wild rye-junegrass-bearberry)

This grassland vegetation type occurs on subxeric Upper Subalpine sites mostly on southerly aspect slopes in Harlequin and Drummond creek valleys. Soils are well drained Brunisolics on colluvial and morainal landforms.

Elymus innovatus is usually dominant with *Arctostaphylos uva-ursi* also frequently important. Other typical species include *Bromus pumpellianus, Achillea millefolium, Anemone multifida, Oxytropis splendens, Fragaria virginiana* and *Myosotis alpestris*. Bryoid cover is low with *Tortula ruralis* common.

20. *Carex nigricans-Antennaria lanata*
(black alpine sedge-everlasting)

This type occurs on mesic to subhygric Alpine sites and is known currently only from the Harlequin and Prospect creek valleys, although it probably occurs elsewhere in the area. Soils are mostly moderately well drained Brunisolics and Regosolics on morainal landforms often with a fluvial veneer. The sites are very late snowbeds which receive seepage throughout the short growing season. The area occupied by this distinctive type is usually small since it occurs as pockets within larger areas of other Alpine vegetation types.

Carex nigricans is by far dominant and characteristically forms a dense turf. Other common species include *Antennaria lanata, Sibbaldia procumbens, Veronica alpina* and *Ranunculus eschscholtzii*. Bryoids have low cover with *Tortula norvegica* and *Cladonia* spp. typical.

21. *Carex aquatilis-Carex rostrata*
(water sedge-beaked sedge)

The sedge fen vegetation type occurs on hydric to subhydric Upper Subalpine to Alpine sites throughout the Cardinal Divide area. Soils are poorly to very poorly drained Organics and Gleysolics developed on fluvial and morainal landforms.

Carex aquatilis is usually dominant with *Carex rostrata* and other *Carex* spp. also important. Other typical species are *Equisetum fluviatile, Equisetum arvense* and *Deschampsia caespitosa*.

Bryoid cover is variable with *Tomenthypnum nitens, Campylium stellatum* and *Drepanocladus revolvens* common. Overall, this type is species-poor.

22. *Erigeron peregrinus-Valeriana sitchensis*
(fleabane-valerian)

This herb meadow vegetation type occurs on mesic to subhygric Upper Subalpine sites throughout the Cardinal Divide area. Soils are moderately well to well drained Brunisolics and Gleysolics on morainal and fluvial landforms.

The fleabane-valerian type is species-rich with *Erigeron peregrinus, Valeriana sitchensis, Anemone occidentalis*, and *Trollius albiflorus* dominant. Other important species include *Senecio triangularis, Artemisia norvegica, Pedicularis bracteosa, Salix arctica* and *Antennaria lanata*. Bryoid cover is generally low with *Tortula norvegica* and *Polytrichum juniperinum* typical.

23. *Artemisia norvegica-Mertensia paniculata-Elymus innovatus*
(boreal wormwood-bluebell-hairy wild rye)

This vegetation type occurs on subhygric to hygric Upper Subalpine to Alpine sites in Harlequin Creek valley. Soils are imperfectly to poorly drained Gleysolics on the lower slopes of morainal and fluvial landforms.

Artemisia norvegica, Mertensia paniculata and *Elymus innovatus* are typically dominant. The type is species-rich with *Aconitum delphinifolium, Salix glauca, Epilobium angustifolium, Phleum alpinum, Polemonium viscosum, Erigeron peregrinus* and *Polygonum viviparum*.

24. *Antennaria lanata-Artemisia norvegica*
(everlasting-boreal wormwood)

This herb meadow type occurs on mesic to subhygric Upper Subalpine to Alpine sites in Harlequin Creek valley. Soils are well to imperfectly drained Brunisolics on morainal landforms.

Antennaria lanata and *Artemisia norvegica* are typically dominant, although many other species occur in this species-rich type. They include *Sibbaldia procumbens, Erigeron peregrinus,*

Phleum alpinum, Polygonum viviparum and *Veronica alpina*.

25. Saxicolous lichen

The saxicolous lichen vegetation type occurs on xeric to subxeric Alpine sites throughout the area on mountain tops and ridge crests at the highest elevations. Soils are Regosolics or *non-soil* of colluvial rubble and frost shattered bedrock.

This vegetation type is very sparsely vegetated. Plant cover is mostly by lichens and a few vascular plants which typically have a prostrate, cushion growth form. Typical lichens include *Rhizocarpon geographicum, Xanthoria elegans, Cetraria tilesii, Acarospora chlorophana, Cladonia pyxidata* and *Cetraria nivalis*. Common vascular plants are *Silene acaulis, Saxifraga oppositifolia, Oxytropis podocarpa, Saxifraga caespitosa, Saussurea nuda* and *Minuartia rubella*.

2.8 Animals

The animals of the Cardinal Divide area have been studied sporadically since at least 1964 by a number of workers from the Provincial Museum of Alberta, the University of Alberta and other groups (Salt 1976a, 1984). To date, 129 bird species and 47 mammal species have been recorded (Appendix 3). Some of the records may be from outside the present boundary of the Cardinal Divide area, since it is impossible to establish the precise location of each record. However, all records are either in or in close proximity to the study area. Information on invertebrates in the Cardinal Divide area is so incomplete that no meaningful description or comparison with other areas can be made. The small amount of information available on invertebrates is discussed below in section 2.9 dealing with glacial refugia.

Bighorn sheep are the only animals in the Cardinal Divide area for which much information is available. The Cardinal Divide area has a habitat capability rating (Myers and Rintoul 1983) of 30% of the area Class III (slight limitation) and 30% Class VI (severe limitation) for sheep year-round. Areas of both summer and winter range occur and the area is also part of a sheep rutting range which extends north and west into Jasper National Park (Holroyd and Van Tighem 1983). The north end of the Cardinal Divide area above Harlequin and Drummond creeks and on Prospect Mountain appears most favorable to sheep in all seasons. Disturbance

by OHV's in the Cardinal River valley may have affected use of the southern part of the area. Aerial surveys (Meyers and Rintoul 1983) show sheep numbers in midwinter to range from 71 to 139 with an average of 100 (five years' observations). These include rams, ewes, lambs and yearlings.

Perhaps the most important animal feature of the Cardinal Divide area is the high species diversity in such a small area. The habitat diversity provided by the altitudinal range, many different kinds of landforms and geological materials and a variety of vegetation types is reflected in the large number of resident mammals and breeding birds. The Front Ranges appear to be an important migration route for birds and many species migrate through the Cardinal Divide area pausing to rest and feed. Others are winter visitors which have migrated from further north. The Cardinal Divide area contains nearly all of the mammals typical of the Rocky Mountains in Alberta in a relatively small area.

2.9 Glacial Refugium

Initial interest in the Cardinal Divide area was sparked by the discovery of Alpine vascular plants which were either previously unknown in Alberta or had a very limited, often disjunct, distribution (Packer and Dumais 1972). This attracted other workers who conducted further studies in a number of fields, including botany (Packer and Vitt 1974, Mortimer 1978, See and Bliss 1980), entomology (Belicek 1976, Pike 1978) and geology (Kilby 1978). Numerous others have collected data on various aspects of the area as part of more widely ranging studies. The area is also used regularly by university and natural history groups for field trips.

Packer and Vitt (1974) were perhaps the first to interpret the species distribution patterns as indicating the area was a Pleistocene glacial refugium. While acknowledging possible gaps in the knowledge of distribution patterns, they accepted the validity of the disjunctions in distribution, rejected explanations based on long distance dispersal or edaphic conditions, and concluded that the disjunctions were best explained by survival of these plants in a glacial refugium during the late Pleistocene.

Subsequent studies in the Cardinal Divide area have further supported this. Mortimer (1978) concluded that while a small number of the species might be explained as habitat disjunctions,

most are best explained by survival in a glacial refugium. As additional evidence, she interpreted the presently restricted ranges as suggesting that the plants which survived in the refugium in small populations became genetically depleted of variability and thus, were less able to adapt and migrate once the ice was gone. She also cited species of predominantly northerly distribution which are disjunct to the Cardinal Divide area (*e.g. Oxytropis jordalii*), species of predominantly southerly distribution which are disjunct to the Cardinal Divide area (*e.g. Telesonix jamesii, Polemonium viscosum*), as well as species with bimodal distributions north and south of the Cardinal Divide area which are disjunct in the area (*e.g. Smelowskia calycina*). The occurrence of *Smelowskia calycina* is itself suggestive of a glacial refugium (Drury and Rollins 1952), since its occurrence in other parts of its range is associated with refugial or unglaciated areas. There is also much interpopulational morphological variation in *Smelowskia calycina* (Greene 1974) which is consistent with the survival of small populations in isolated refugia. As well, the distribution pattern and relation to other closely related taxa in *Oxytropis jordalii* (Elisens 1978) and *Minuartia austromontana* (Wolf *et al.* 1979) suggests a refugium in the Cardinal Divide area or the Front Ranges. The geographic pattern of variation in *Arctostaphylos uva-ursi* (Packer and Denford 1974) and *Cassiope tetragona* (Denford and Karas 1975), including collections from the Cardinal Divide area, are also consistent with a Front Range refugium, although apparent post-glacial migration has made the situation less clear than in some of the species above with more restricted ranges.

Seven species of mosses show range disjunctions or other distribution patterns which suggest a glacial refugium in the Cardinal Divide area. These include *Bryobrittonia longipes, Didymodon johansenii, Encalypta brevicolla, E. brevipes, E. mutica, Hypnum procerrimum* and *Orthotrichum pylaisii* (Packer and Vitt 1974, Horton and Murray 1976, Horton 1979 and 1982). Horton (1982), reviewing the bryological evidence, concludes that the Cardinal Divide area was probably a glacial refugium or part of an ice-free corridor but that the inference of this from present-day distributions is not clear-cut.

Other than *Smelowskia calycina* (Greene 1974) and perhaps *Cassiope tetragona* (Denford and Karas 1975), localized differentiation due to prolonged isolation is not apparent in plant populations at present, although there is some evidence of this in butterflies (Pike 1978).

Zoological evidence of a refugium comes from beetles (Belicek 1976), butterflies (Pike 1978) and crustaceans (Clifford and Bergstrom 1976). Pike (1978) found in the Cardinal Divide area both a disjunct species of tundra butterfly (*Boloria improba youngi*) and three butterflies endemic to the Cardinal Divide area (*Boloria eunomia nichollae, Boloria napaea reifii* and an ecological form of *Oeneis melissa beani*). All suggest a refugium in the Front Ranges in the vicinity of the Cardinal Divide area. Three species of beetles with disjunct populations in the Front Ranges (Belicek 1976) provide additional evidence. The crustacean, a blind, cave-dwelling isopod (*Salmasellus steganothrix*), is an endemic species known only from a cave spring near Cadomin and from Horseshoe Lake in Jasper National Park, about 50 km southwest of the Cardinal Divide area (Clifford and Bergstrom 1976). Other species of this group are associated with unglaciated areas and the occurrence of an endemic species of this group suggests a glacial refugium. A disjunct occurrence of another crustacean near the Cardinal Divide area (Daborn 1976) has been considered as also indicative of a refugium. However, Daborn considers the disjunction to be due to long distance dispersal by migratory waterfowl and thus its significance is questionable.

Evidence from glacial history cited above (section 2.3) suggests that parts of the Cardinal Divide area may have been ice-free during the late Pleistocene and may have been part of a series of ice-free areas or within an ice-free corridor along the Front Ranges. Thus, while the glacial history of the Cardinal Divide area is not entirely clear, it seems generally consistent with the theory of a late Pleistocene refugium as suggested by the biological evidence.

The convergence of evidence from several different disciplines bolsters the case for concluding that the Cardinal Divide area was a late Pleistocene refugium. However, some questions remain. The glacial history of the Cardinal Divide area has yet to be worked out in more detail before the geological evidence can be judged satisfactorily. Likewise, supportive animal evidence is scanty, perhaps primarily because appropriate studies have not been done. This lack of evidence should not be taken as indicating anything positive or negative about the refugial theory.

Recent plant collections have increased knowledge of the ranges of some of the significant species as collectors have reached areas less accessible than the Cardinal Divide area, *e.g. Salix reticulata* and *Saxifraga nivalis* (Achuff and Corns 1984), *Polemonium viscosum* (Lee *et al.*

1982), *Braya purpurascens* (Achuff 1982), *Bryobrittonia longipes* (Horton 1982). These range extensions have been primarily along the Front Ranges and it is clear that more collecting must be done in the Alpine Ecoregion, especially in the Front Ranges, before the blanks on distribution maps can be accepted confidently as indicating absence of the species. However, it appears that these species are largely confined to the Front Ranges which is consistent with the Cardinal Divide area being part of an ice-free corridor in the late Pleistocene. In any case, the concentration of these species in the Cardinal Divide area is remarkable and constitutes a strong reason for preserving the area.

3. COMPARISON WITH OTHER AREAS

3.1 Introduction

In the following comparison of the Cardinal Divide area with other areas in the Rocky Mountains, the emphasis is on features of the Cardinal Divide area which occur in the other areas, and less consideration is given to features which occur in the other areas but not in the Cardinal Divide area. The information used here comes from a wide variety of sources which had various objectives, methods and scales, from a cursory reconnaissance of large areas to detailed studies of small areas. There are not comparable levels of information for all features, *e.g.* soils information is generally at the Order level, a very generalized scale, while floristic information is at the much more detailed scale of the biological species. In many cases no information is available for certain features of an area. These disparities in information greatly complicate comparative analysis for, strictly speaking, no valid comparisons are possible without comparable data. Perhaps the most serious difficulty is deciding whether a feature is truly absent or whether it is only information on that feature which is absent. Thus, the evaluations of comparability here involve a large degree of the author's judgement and should be regarded as tentative.

The comparisons are organized by area, rather than by feature although, in some cases, features must be considered across all areas to evaluate a feature or area in a provincial perspective. The comparisons are summarized (Table 4) using four classes of similarity. The first class (shown by = in Table 4) indicates that the feature which occurs in the Cardinal Divide area is present in the other area in essentially the same form. The second (shown by s in Table 4) indicates that the feature seems similar but information is inadequate to place it in the first class. The third class (shown by – in Table 4) indicates that the feature is absent or different. The fourth class (shown by ? in Table 4) indicates information is lacking to make a comparison.

Since the information is disparate for many features, below are comments on the nature of the information used for each of the major subject areas.

Table 4. Comparison of the Cardinal Divide area with other Rocky Mountain areas. Areas are: **KW** - Kakwa, **WW** - Willmore Wilderness Park, **BJ** - Banff and Jasper National Parks, **RM** - Ram Mountain, **WG** - White Goat Wilderness Area, **SF** - Siffleur Wilderness Area, **GR** - Ghost River Wilderness Area, **KN** - Kananaskis, **PM** - Plateau Mountain, **BH** - Beehive, **WL** - Waterton Lakes National Park. Symbol '=' indicates that the feature is essentially the same; 's' that the feature seems similar but information is inadequate; '–' that the feature is absent or different; '?' that information is lacking to make a comparison.

	Other Rocky Mountain Areas										
	KW	WW	BJ	RM	WG	SF	GR	KN	PM	BH	WL
Climate	s	s	=	=	=	=	=	–	–	–	–
Bedrock geology	=	=	=	s	=	=	=	=	s	s	s
Landforms	=	=	=	–	=	=	s	=	s	=	=
Periglacial features	s	s	=	?	=	=	s	=	=	?	?
Rock glaciers	–	–	–	–	–	–	–	–	–	–	–
Glacial history	?	?	s	s	s	s	s	s	s	?	–
Soils	=	=	=	s	=	s	s	=	s	=	=
Floristic overlap (%)	69	66	99	57	98	66	38	76	60	59	71
Vegetational overlap (%)	48	60	88	16	60	56	28	56	24	32	16
Faunal overlap (%)	?	?	99	?	?	?	?	97	?	?	97

Climate

The classification of Powell (1978) is used to make comparisons. This classification is based on scattered stations which are seldom in the areas being compared here and the data used are from only the growing season, usually May through September. Thus, the classification should be regarded as a first approximation which probably shows only gross climatic differences in the Rocky Mountains.

Bedrock Geology

The bedrock geology information is qualitative, *i.e.* it only indicates presence or absence and not how much of each stratum is present. Nor does it deal with facies changes which are sometimes considerable between areas, since this level of detail is not available for all areas.

The overview of Reimchen and Bayrock (1977) is used for comparisons. However, it is generalized and necessarily lacks the detail needed to fully understand differences in glacial history and landforms among the areas. For landforms, there is no overview or uniform system used, nor is there any quantitative information. For example, it may be known that rock glaciers occur in an area but it is not clear what types or how many of each are present.

Soils

Soil survey in the mountains is a relatively recent phenomenon of about the last 15 years and many areas of the mountains have only a cursory survey. Thus, with current data it is only possible to make generalized comparisons at the Order level and, as for climatic information, these are unlikely to show differences because of the gross classification level.

Flora

Floristic information may seem to be the most accurate since the data consist of a large number of small, discrete units. However, it is very sensitive to collector effort and bias — areas or habitats are less collected if they are remote, at high altitudes or wet. Also, groups that are hard to identify are often less reported. Thus, the information in Appendix 1 is probably quite incomplete.

Floristic overlap — the percentage of vascular species in the Cardinal Divide area which occurs in the other area — was computed. This is not the same as *floristic similarity* in which the total floras of *both* areas are compared. The values fall into four groups (Table 4). The first includes Banff and Jasper National Parks (99%) and the White Goat Wilderness Area (98%) with very high overlap. The second group, with an overlap of 66 to 76%, includes Kananaskis, Waterton Lakes National Park, Kakwa, Willmore Wilderness Park and the Siffleur Wilderness Area. The third group comprises Plateau Mountain, Beehive and Ram Mountain with values of 57 to 60%. The final group contains only the Ghost River Wilderness Area with an overlap of 38%. This lowest value is certainly an artifact of few collections from the Ghost River area.

Vegetation

Among the studies used there are large differences in methods, scale and criteria of recognition. An attempt has been made to standardize the category *vegetation type* by, where necessary, combining other authors' vegetation types to a common scale. It is much more difficult to split another worker's larger, more heterogeneous vegetation type and this was seldom done. Large gaps in the vegetation information make the comparison (Table 3) quite tenuous. *Vegetational overlap* — the percentage of vegetation types in the Cardinal Divide area that occur in the other area — was computed (Table 4). The values fall into four groups. The first contains Banff and Jasper National Parks with 88% overlap. The second, with 48% to 60% overlap, consists of Willmore Wilderness Park, White Goat Wilderness Area, Siffleur Wilderness Area, Kananaskis and Kakwa. The third, 24% to 32 %, includes Beehive, Ghost River Wilderness Area and Plateau Mountain. The fourth, Waterton Lakes National Park and Ram Mountain, have least overlap at only 16%.

Animals

Animal information, other than for ungulates (moose, mule deer, white-tailed deer, sheep, goat, elk and caribou), is very weak for most areas. Animal inventory requires a large number of sample methods and must occur over the whole year, since some are present or evident only at certain times. Adequate invertebrate data are lacking for all areas. Thus, with the exception of Banff and Jasper National Parks, Kananaskis and Waterton Lakes National Park, it is impossible to make meaningful comparisons (Appendix 3).

3.2 Kakwa

The climate of the Kakwa area appears comparable to that of the Cardinal Divide area (Powell 1978). However, this is a rather generalized classification and the location of Kakwa close to the Continental Divide and the occurrence of several species of plants (Jacques 1978) suggests suggests significant differences. The bedrock geology of the Kakwa area is similar to that of the Cardinal Divide area except that beds of Permian age and older (Fig. 2) do not outcrop although they are probably present at depth (Ferguson 1980). The landforms are essentially the same in both areas (Ferguson 1980, Twardy and Corns 1980). Neither periglacial features nor rock glaciers are reported although the former most certainly occur at high altitudes. The glacial

history of the Kakwa area is insufficiently known to make a comparison with the Cardinal Divide area. The soils of the two areas are comparable (Twardy and Corns 1980) although the lack of comparable information for the Cardinal Divide area makes more detailed comparison impossible. There is a 69% floristic overlap between the two areas. Species which occur in the Cardinal Divide area but not in the Kakwa area include disjuncts such as *Telesonix heucheriformis* and *Oxytropis jordalii*. This may indicate differences in historical or current environmental factors between the two areas. Jacques (1978) lists a number of disjunct species in the Kakwa area and cites current climatic conditions as the major factor involved. Vegetationally, there is a 48% overlap with the greatest difference in shrub and open forest vegetation types. As in the Cardinal Divide area, *Dryas integrifolia* is an important component of some vegetation types. Insufficient animal information is available to make a comparison.

3.3 Willmore Wilderness Park

The climate of the Willmore is similar to that of the Cardinal Divide area on a gross scale. However, the classification is based on limited data and within the Willmore itself there are probably significant climatic differences from east to west. Thus, it is likely at most that the Front Range, eastern portion of the Willmore is comparable climatically to the Cardinal Divide area. All of the bedrock units of the Cardinal Divide area also occur in the Willmore as well as some which do not occur in the Cardinal Divide area. Landforms and periglacial features are likely similar (Ferguson 1980) although detailed information is lacking. Rock glaciers have not been reported from the Willmore, although they are expected. Soils of the two areas appear comparable (Ferguson 1980). The glacial history of the area is too poorly known to make a comparison, particularly in regard to possible glacial refugia. Floristically, there is a 66% overlap. Many of the species of the Cardinal Divide area which are absent in the Kakwa area are also absent in the Willmore, suggesting some consistent differences from the Cardinal Divide area. Collections of several significant species, *e.g. Ranunculus nivalis* and *Braya purpurascens* (Packer and Dumais 1972), in the Front Ranges of the Willmore suggest the possible occurrence of a refugium there (Packer and Vitt 1974, Vitt and Koponen 1976). The vegetational overlap is 60% with the greatest difference in shrub vegetation types (Alberta Ecological Survey 1976). Insufficient information on animals is available to make a comparison.

3.4 Banff and Jasper National Parks

The Alpine portion of the Front Ranges in Banff and Jasper National Parks is quite similar to the Cardinal Divide area in many respects. Climatically, both are in Powell's (1978) group 10. The bedrock geology (Holland and Coen 1982) is essentially the same and there is much similarity in geomorphology — landforms and periglacial features. Glacial history is probably also similar but sufficiently detailed information is lacking. Banff and Jasper have rock glaciers (Luckman and Crockett 1978) but none like the one in SW8 in Drummond Creek valley. Soils of the Cardinal Divide area are essentially the same as those of Banff and Jasper, except that Banff and Jasper also have Cryosolics with permafrost (Achuff and Coen 1980) in the Front Ranges. So far, permfrost is not known in the Cardinal Divide area. The flora of the Cardinal Divide area is very similar to that of Banff and Jasper. The overlap is 99%, highest of any area. Only three species which occur in the Cardinal Divide area (*Oxytropis jordalii, Polemonium viscosum,* and *Eriophorum chamissonis*) are not known from Banff and Jasper. There is also great similarity in vegetation types with an 88% overlap which is highest of any area compared. There is also very high overlap (99%) in birds and mammals with only two species reported from the Cardinal Divide area not recorded in Banff and Jasper (wood duck, woodchuck).

Banff and Jasper overall are much more diverse than the Cardinal Divide area and many features occur there which are absent in the Cardinal Divide area (Holland and Coen 1982, Holroyd and Van Tighem 1983). Nevertheless, the Cardinal Divide area does contain features not found in these larger National Parks.

3.5 Ram Mountain

Ram Mountain occurs in the Front Ranges as does the Cardinal Divide area but Ram Mountain is much smaller which is probably a major reason for many of the differences. Climatically, both areas are in the same group in Powell's (1978) classification. Bedrock geology is probably the same (Holter and McLaws 1977) but comparable information is not available for Ram Mountain. The Cardinal Divide area has greater diversity of landforms due to its greater size. Ram Mountain has no rock glaciers and comparable periglacial features are not known. Soils diversity on Ram Mountain is probably also less although adequate information is lacking.

Floristic overlap is 57% and the Cardinal Divide species which are absent here suggest a scarcity of mesic habitats. *Dryas integrifolia* is an important constituent of several communities (Johnson 1975) as in the Cardinal Divide area. Vegetational overlap is 16%, the lowest value. This can be attributed to both the small size and limited environmental diversity of Ram Mountain. As with the flora, the missing vegetation types suggest a lack of mesic and wetter habitats. Thus, while a broad climatic classification (Powell 1978) places Ram Mountain in the same category as the Cardinal Divide area, the floristic and vegetational data indicate marked microclimatic and perhaps mesoclimatic differences between the two areas. Ram Mountain contains a population of bighorn sheep as does the Cardinal Divide area area, but information on them and other animals is insufficient to make comparisons.

3.6 White Goat Wilderness Area

Climatically the White Goat Wilderness Area has been placed in the same broad group as the Cardinal Divide area, although no data used in the classification (Powell 1978) came from the White Goat. The bedrock geology of the White Goat is the same as the Cardinal Divide area (Price and Mountjoy 1970, Holter and McLaws 1977). Landforms and periglacial features also appear comparable (author's observations 1981, Lee *et al.* 1982, Reimchen and Bayrock 1977). Only one rock glacier is known from the White Goat (Lee *et al.* 1982), in the Cataract Creek valley. The glacial history of the White Goat appears similar to that of the Cardinal Divide area given its Front Range position, but the details are unclear. The soils of the two areas appear comparable at a broad level. Floristic overlap is 98%, the second highest value. This appears partly due to similarities in history and present environment and partly to a comparable level of plant collecting effort. Many of the significant species of the Cardinal Divide area also occur in the White Goat (*e.g. Oxytropis jordalii, Rhododendron lapponicum, Polemonium viscosum*). Vegetational overlap is 60%, the second highest value. The vegetational differences suggest a scarcity of mesic habitats. This may be due to a drier mesoclimate in the Front Ranges or inadequate information due to limited survey may also contribute to the apparent differences. Insufficient information on animals makes comparisons between the two areas impossible.

3.7 Siffleur Wilderness Area

The climate of the Siffleur Wilderness Area is comparable to that of the Cardinal Divide area (Powell 1978). The bedrock geology and landforms are also essentially the same (Price and Mountjoy 1970, Holter and McLaws 1977, Reimchen and Bayrock 1977). Several rock glaciers occur in the area (Lee *et al.* 1982) as do several small ice glaciers in cirques. Soils are probably also very similar but adequate data are lacking. Floristic overlap is 66% which is in the group with second highest values. Most of the significant species of the Cardinal Divide area are not reported from the Siffleur. This seems odd in view of the large number of them that occur in the nearby White Goat Wilderness Area. The differences may be real or only due to less collecting effort in the Siffleur. Vegetational overlap is 56% with major differences in shrub and herb-dwarf shrub types. As in the White Goat, survey effort may be a factor (Lee *et al.* 1982). Animal data are insufficient to make a comparison.

3.8 Ghost River Wilderness Area

The Ghost River Wilderness Area is in the same climatic group as the Cardinal Divide area in Powell's (1978) classification. However, the Ghost River area is probably drier than the Cardinal Divide area as indicated by a negative summer water balance (McGregor 1979) *vs.* a positive balance for the Cardinal Divide area (Table 1). Both bedrock and landforms appear comparable to those of the Cardinal Divide area (Holter and McLaws 1977, Reimchen and Bayrock 1977, McGregor 1979). Periglacial features and glacial history are probably similar but adequate information is lacking. Rock glaciers are not reported from the Ghost River area. Floristic overlap is 38%, the lowest value, and is certainly due to very limited information and field work, as indicated by the absence of common, widespread species in the lists available (Brathay Exploration Group 1981). Vegetational overlap at 28% reflects the same paucity of data rather than real differences due to history or present environment. Animal information is also insufficient to make comparisons.

3.9 Kananaskis

The climate of the Kananaskis area is not similar to that of the Cardinal Divide area (Powell 1978). Bedrock geology is essentially the same as the Cardinal Divide area (Holter and McLaws 1977, Anderson 1979). Landforms and periglacial features also appear comparable (Anderson 1979). The glacial history of the eastern part of the area appears similar (Jackson 1977) but detailed information is lacking. Rock glaciers are present in the Kananaskis area. Soils are essentially the same (Anderson 1979). Floristic overlap is 76%, the third highest value. Many of the significant species of the Cardinal Divide area occur in the Kananaskis area. Kananaskis also has a number of significant species of its own (Jacques and Legge 1974) including the endemic species *Draba kananaskis*. Vegetational overlap is 56%, a value in the second highest group. The vegetation of the Kananaskis area has been well described by a number of workers (Trottier 1972, Jacques and Legge 1974, Kondla 1978, Natural Areas Program 1981a-e). Most differences are in the shrub vegetation types. Overlap of bird and mammal species (Salt 1976a, Wiseley 1979) which occur in both areas is very high (97%). Invertebrate data are insufficient to make comparisons.

3.10 Plateau Mountain

The climate of Plateau Mountain is not comparable to that of the Cardinal Divide area (Powell 1978). Bedrock geology appears similar (Holter and McLaws 1977, Karpuk and Levinsohn 1980) but additional information is needed. Glacial history (Alley 1973, Reimchen and Bayrock 1977) and landforms (Reimchen and Bayrock 1977, Strong 1979) also appear similar but information is incomplete. Plateau Mountain has comparable periglacial features and also has features, such as strongly patterned ground with large polygons (Bryant and Scheinberg 1970), an ice cave and permafrost, which the Cardinal Divide area lacks. Rock glaciers have not been reported from Plateau Mountain. Soils are probably similar (Strong 1979) but less variety can be expected since Plateau Mountain is a smaller area. Floristic overlap is 60%. The differences appear to be largely due to a shift in regional floras which occurs at about 50°N (Ogilvie 1962). Vegetational overlap is 24%, the second lowest value. The differences are partly due to the smaller size of Plateau Mountain, and perhaps also due to a somewhat drier climate. Plateau

Mountain contains some features, such as *Pinus albicaulis* open forest at treeline, which do not occur in the Cardinal Divide area (Griffiths 1982). Animal information is too incomplete to make any comparisons.

3.11 Beehive

Beehive has a different climate than the Cardinal Divide area (Powell 1978). This may be in part due to its position in the Main Ranges rather than the Front Ranges. The bedrock geology is somewhat different but it is not clear whether the differences are mainly nomenclatural or not (Karpuk and Levisohn 1980). The range of landforms is the same as for the Cardinal Divide area, as are the soils (Karpuk and Levinsohn 1980). The glacial history appears to be quite different (Alley 1973). No rock glaciers are known from the Beehive area and information on periglacial features is lacking. Floristic overlap is 59%, one of the lowest values. This probably reflects the change in the regional flora which occurs at about 50°N (Ogilvie 1962). Vegetational overlap is only 32% indicating a major difference in the vegetation of the two areas (Griffiths 1981). Animal information is inadequate to make a comparison with the Cardinal Divide area.

3.12 Waterton Lakes National Park

The climate of Waterton Lakes National Park is very different from that of the Cardinal Divide area (Anderson 1978, Powell 1978). Waterton is influenced by a greater frequency of maritime air masses due to a storm track which extends inland from the Pacific Ocean along the international border (Ogilvie 1962) resulting in a summer-dry, winter-wet precipitation regime (Reinelt 1967, 1970). Springtime precipitation is the highest in Alberta (Stringer 1973) and the park has slightly higher precipitation and warmer temperatures than the rest of Alberta (Longley 1967). The bedrock geology (Price 1962) and glacial history (Stalker and Harrison 1977, Rutter 1978, Alley 1973) are quite different from the Cardinal Divide area. Landforms and soils (Coen and Holland 1976) are comparable at the scale used here. Information of periglacial features is scant and no rock glaciers have been reported. Floristic overlap is 71% but this gives a misleading impression. The vascular flora of Waterton is about 965 species (Kuijt 1982) and while many of the Cardinal Divide area species occur in Waterton, overall the Waterton flora is very different. Many of the species are limited to the Waterton area or south

of Crowsnest Pass and these constitute perhaps 10% of the total flora of the province (Kuchar 1973). The flora of Waterton is very rich and contains about 55% of the species in Alberta (Kuijt 1982). Vegetational overlap is only 16%, the lowest value, and reflects the very different conditions in the Waterton area. There are also some vegetation types unique to Waterton (Kuchar 1973), *e.g.* some *Pinus albicaulis* and *Pinus flexilis* communities. The birds (Sharp 1973) and mammals (Nielsen 1973) of Waterton, however, are quite comparable to those of the Cardinal Divide area, as indicated by a 97% overlap.

4. CONCLUSIONS AND RECOMMENDATIONS

The Cardinal Divide area contains many features, both physical and biological, which are representative of the Alpine Ecoregion in the northern part of the Front Ranges of the Rocky Mountains in Alberta. The Cardinal Divide area also contains a number of *special features*, including:

1. a *rock glacier* which, in form, appears unique in the province. The area contains additional rock glaciers which are probably similar to those of other areas.
2. a wide variety of *patterned ground* features which are the result of periglacial processes.
3. geological evidence which suggests that the Cardinal Divide area was *unglaciated* during the late Pleistocene.
4. a diversity of *waterfalls, cascades* and small *glens* in the upper part of the Cardinal River.
5. thirty-five *significant plant species*, about 12% of the flora, which are either *rare* provincially or geographically significant, mostly *disjuncts*.
6. *hybridization* between species in the genera *Dryas* and *Phyllodoce*.
7. three *vegetation types* (*Salix drummondiana-Thalictrum venulosum, Artemisia norvegica-Mertensia paniculata-Elymus innovatus, Antennaria lanata-Artemisia norvegica*) which are not currently known from anywhere else in Alberta.
8. a *high diversity of birds and mammals* which is as great as much larger areas and includes nearly all of the mammals that occur in the Rocky Mountains of Alberta.
9. *disjunct* and *endemic* insects.
10. a *glacial refugium*, as supported by a convergence of geological and biological evidence.
11. *Alpine tundra* which is extremely sensitive to disturbance and is being currently abused by uncontrolled OHV traffic.

Due to the lack of information on certain features of the Cardinal Divide area and on many other areas in the province, it is very difficult to place the Cardinal Divide area in an accurate provincial perspective. These information weaknesses include both a simple lack of information (especially geomorphology, glacial history, soil, vegetation, flora and animals) as well as information which is not of sufficient scale or comparable classification (climate,

geomorphology, glacial history, soils and vegetation). However, from current information it is apparent that the Cardinal Divide area contains a rich variety of physical and biological features, some of which are representative of the Alpine Ecoregion in the northern Front Ranges and many of which are special. There is some overlap of features in the Cardinal Divide area with other conserved areas in Alberta, but the richness and constellation of features is unduplicated elsewhere. Thus, it is recommended that the Cardinal Divide area be retained as part of a provincial system of conserved areas. Designation as an Ecological Reserve might be most appropriate in view of the scientific value of the area and its use, both past and current, for scientific research and educational activities. Some indication of this scientific value can be seen in the large number of scientific papers and theses in the Literature Cited section which have derived all or part of their information from the Cardinal Divide area. Additional evidence comes from inclusion of the Cardinal Divide area in a candidate *Natural Area of Canadian Significance* (Parks Canada 1984). This designation is derived from a nation-wide review and selection of areas which are outstanding representatives of various natural regions.

No changes in the boundary of the Cardinal Divide area are suggested at this time. However, additional information may necessitate some boundary changes in the future.

Management of OHV traffic in the Cardinal Divide area is needed. Currently, OHV use is uncontrolled and causing damage to the vegetation and soils, and may be disrupting wildlife in the area. The means, legislative and administrative, to control OHV use should be provided as soon as possible.

The attempt to compare the Cardinal Divide area with other areas in the Alpine Ecoregion has shown that further investigation of both the Cardinal Divide area and other areas is needed. In the Cardinal Divide area, first priority should be a more detailed investigation of the glacial history, flora (especially bryophytes and lichens) and invertebrate animals. Of secondary priority are soils, vertebrate animals and vegetation.

Outside the Cardinal Divide area, much more information is needed on the Alpine Ecoregion of the Front Ranges. Initially, information on flora and vegetation should be gathered since it is most easily collected and provides a good indication of current environment and the possibilty of glacial refugia. Among currently conserved areas, the Ghost River, Siffleur and White Goat Wilderness Areas and Willmore Wilderness Park should receive the top priority. Outside of

presently conserved areas, information is needed from the First Range and Bighorn Range, east of the White Goat Wilderness Area and from the Ram Range between the North Saskatchewan and Clearwater rivers east of Banff National Park. Another major information gap is the virtual lack of information on non-ungulate animals in all areas. Of the 11 areas compared with the Cardinal Divide area, only Banff and Jasper National Parks, Kananaskis and Waterton Lakes National Park had enough information to permit a comparison of the animals. Finally, comparison of the vegetation of areas is hampered by the lack of a comprehensive vegetation type classification. Classifications exist for other components, *e.g.* soil, landforms, plant and animal species, but not for vegetation. Development of such a classification would require first, collection of information from areas of the mountains which lack data and then, data analysis and synthesis to produce the classification.

In summary, despite the very real short-comings in information about both the Cardinal Divide area and other conserved areas in the Rocky Mountains and the difficulties thus imposed on comparisons, the Cardinal Divide area emerges as an extremely valuable area with a great diversity of physical and biological features unduplicated elsewhere in the province.

APPENDIX 1

Vascular flora of the Cardinal Divide area and occurrence in other Rocky Mountain areas of Alberta. Areas and sources are: **KW** - Kakwa (Jacques 1978), **WW** - Willmore Wilderness Park (Alberta Ecological Survey 1976), **BJ** - Banff and Jasper National Parks (Achuff 1982), **RM** - Ram Mountain (Johnson 1975), **WG** - White Goat Wilderness Area (Lee *et al.* 1982), **SF** - Siffleur Wilderness Area (Lee *et al.* 1982), **GR** - Ghost River Wilderness Area (Brathay Exploration Group 1981), **KN** - Kananaskis (Natural Areas Program 1981a-e, Kondla 1978), **PM** - Plateau Mountain (Griffiths 1982), **BH** - Beehive (Griffiths 1981), **WL** - Waterton Lakes National Park (Kuchar 1973, Kuijt 1982).

	Other Rocky Mountain Areas										
	KW	WW	BJ	RM	WG	SF	GR	KN	PM	BH	WL
LYCOPODIACEAE											
Lycopodium alpinum	+	+	+	–	–	+	+	+	–	+	–
SELAGINELLACEAE											
Selaginella densa	+	+	+	+	+	+	+	+	+	+	+
Selaginella rupestris	–	+	+	–	–	+	+	+	–	–	–
EQUISETACEAE											
Equisetum arvense	+	+	+	+	+	+	+	+	–	+	+
Equisetum scirpoides	+	+	+	+	+	+	+	+	+	+	+
Equisetum variegatum	+	+	+	–	+	–	–	+	+	+	+
OPHIOGLOSSACEAE											
Botrychium lunaria	+	+	+	+	+	+	+	+	+	–	+
POLYPODIACEAE											
Cystopteris fragilis	+	+	+	+	+	+	–	+	+	+	+
CUPRESSACEAE											
Juniperus communis	+	+	+	+	+	+	+	+	+	+	+
Juniperus horizontalis	–	+	+	+	+	+	+	+	+	+	+
PINACEAE											

	Other Rocky Mountain Areas										
	KW	WW	BJ	RM	WG	SF	GR	KN	PM	BH	WL
Abies lasiocarpa	+	+	+	+	+	+	+	+	+	+	+
Picea engelmannii	+	+	+	+	+	+	+	+	+	+	+
Pinus contorta	+	+	+	+	+	+	+	+	+	+	+
SALICACEAE											
Salix alaxensis	–	–	+	+	+	–	–	–	–	–	–
Salix arbusculoides	–	–	+	+	+	–	–	–	–	–	–
Salix arctica	+	+	+	+	+	+	–	+	+	+	+
Salix barclayi	+	+	+	–	+	+	–	–	–	–	+
Salix barrattiana	+	+	+	–	+	+	+	+	+	+	–
Salix drummondiana	+	–	+	–	+	+	–	+	+	–	+
Salix farriae	–	–	+	–	+	+	–	+	+	+	+
Salix glauca	+	+	+	+	+	+	+	+	+	+	+
Salix nivalis	+	+	+	+	+	+	+	+	+	+	+
Salix reticulata	+	+	+	–	+	–	–	–	–	–	–
Salix vestita	+	+	+	+	+	+	+	+	+	+	+
BETULACEAE											
Betula glandulosa	+	+	+	–	+	+	–	+	+	+	+
Betula pumila	+	+	+	+	+	+	+	+	–	–	+
POLYGONACEAE											
Eriogonum androsaceum	–	–	+	+	+	–	–	+	–	+	+
Oxyria digyna	+	+	+	+	+	+	+	+	+	+	+
Polygonum viviparum	+	+	+	+	+	+	+	+	+	+	+
Rumex acetosa ssp. *alpestris*	+	+	+	+	+	+	–	+	+	+	+
PORTULACACEAE											
Claytonia lanceolata	+	+	+	–	+	+	+	+	–	+	+
Claytonia megarhiza	–	–	+	+	+	+	+	+	–	+	+
CARYOPHYLLACEAE											
Cerastium arvense	+	+	+	+	+	+	–	+	+	+	+
Cerastium beeringianum	+	+	+	+	+	+	–	+	+	+	+
Minuartia austromontana	–	+	+	+	+	+	–	+	+	+	+
Minuartia biflora	–	–	+	–	+	–	–	–	–	–	+
Minuartia obtusiloba	+	+	+	+	+	+	–	+	+	+	+
Minuartia rubella	+	+	+	+	+	–	–	+	+	+	+
Silene acaulis	+	+	+	+	+	+	+	+	+	+	+
Silene parryi	–	–	+	+	+	+	+	+	+	–	+
Silene uralensis	–	+	+	–	+	–	–	+	–	–	+
Stellaria longipes	+	+	+	+	+	–	–	+	–	+	+

	Other Rocky Mountain Areas										
	KW	WW	BJ	RM	WG	SF	GR	KN	PM	BH	WL
RANUNCULACEAE											
Aconitum delphinifolium	+	+	+	–	+	–	–	–	–	–	–
Anemone lithophila	+	+	+	+	+	+	+	+	+	+	+
Anemone multifida	+	+	+	+	+	+	–	+	+	+	+
Anemone occidentalis	+	+	+	–	+	+	+	+	+	+	+
Anemone richardsonii	–	+	+	–	+	–	–	–	–	–	–
Aquilegia flavescens	–	+	+	+	+	+	+	+	+	+	+
Delphinium glaucum	+	+	+	+	+	+	+	+	+	+	–
Ranunculus eschscholtzii	+	–	+	+	+	+	+	+	+	+	+
Ranunculus pedatifidus	–	–	+	+	+	–	–	–	+	–	+
Ranunculus pygmaeus	+	–	+	–	+	+	–	–	+	–	–
Thalictrum occidentale	+	+	+	–	+	–	+	+	+	+	+
Trollius albiflorus	+	+	+	–	+	+	+	+	+	+	+
PAPAVERACEAE											
Papaver kluanensis	–	+	+	+	+	–	+	+	–	–	–
CRUCIFERAE											
Arabis drummondii	+	+	+	+	+	+	–	+	+	+	+
Braya humilis	–	–	+	+	+	–	–	–	–	–	–
Braya purpurascens	–	–	+	–	+	–	–	–	–	–	–
Cardamine umbellata	+	+	+	–	+	–	–	–	–	–	+
Draba albertina	–	–	+	+	+	–	–	–	–	–	–
Draba aurea	+	+	+	+	+	+	–	+	+	+	+
Draba borealis	+	–	+	–	+	+	–	–	+	–	–
Draba cana	+	–	+	+	+	–	–	–	–	+	+
Draba crassifolia	+	–	+	–	+	–	–	+	+	–	+
Draba fladnizensis	+	–	+	+	+	–	–	–	–	–	–
Draba incerta	+	+	+	+	+	+	+	+	+	+	+
Draba lonchocarpa	+	–	+	+	+	–	–	–	+	+	+
Draba macounii	–	–	+	–	+	–	–	–	–	–	–
Draba nivalis	–	+	+	–	+	–	–	+	+	–	–
Draba oligosperma	+	+	+	+	–	–	–	+	+	–	–
Draba paysonii	–	+	+	+	+	–	–	–	–	+	+
Draba porsildii	+	–	+	+	+	–	–	–	+	–	–
Lesquerella arctica	–	–	+	+	+	–	–	–	–	–	–
Smelowskia calycina	–	–	+	+	+	–	+	+	+	+	+
CRASSULACEAE											
Sedum lanceolatum	+	+	+	+	+	+	+	+	+	+	+
SAXIFRAGACEAE											
Mitella nuda	+	+	+	–	+	+	–	+	–	+	+

	Other Rocky Mountain Areas										
	KW	WW	BJ	RM	WG	SF	GR	KN	PM	BH	WL
Parnassia fimbriata	+	+	+	+	+	+	+	+	+	+	+
Parnassia kotzebuei	–	–	+	+	+	+	+	+	+	+	+
Parnassia palustris	+	+	+	+	–	+	–	+	–	–	+
Ribes oxyacanthoides	–	+	+	+	+	+	–	+	–	–	+
Saxifraga adscendens	+	+	+	+	+	+	+	+	+	–	+
Saxifraga aizoides	+	+	+	+	+	+	+	+	–	–	–
Saxifraga bronchialis	–	–	+	+	+	+	+	+	+	+	+
Saxifraga caespitosa	+	+	+	+	+	+	+	+	+	+	+
Saxifraga cernua	–	+	+	+	+	+	+	+	+	+	+
Saxifraga flagellaris	+	+	+	+	+	–	–	–	–	–	–
Saxifraga lyallii	+	+	+	–	+	+	+	+	+	+	+
Saxifraga nelsoniana	+	+	+	–	+	–	–	–	–	–	+
Saxifraga nivalis	+	–	+	–	+	–	+	+	–	–	–
Saxifraga occidentalis	+	+	+	–	+	+	–	+	+	+	+
Saxifraga oppositifolia	+	+	+	+	+	+	+	+	+	+	+
Saxifraga tricuspidata	+	+	+	–	+	–	–	–	–	–	–
Telesonix heucheriformis	–	–	+	–	+	–	–	–	–	–	–
ROSACEAE											
Dryas integrifolia	+	+	+	+	+	+	–	+	–	–	–
Dryas octopetala ssp. *hookeriana*	+	+	+	–	+	+	+	+	+	+	+
Fragaria virginiana	+	+	+	+	+	+	+	+	+	+	+
Potentilla diversifolia	+	+	+	+	+	+	+	+	+	+	+
Potentilla fruticosa	+	+	+	+	+	+	+	+	+	+	+
Potentilla gracilis	–	–	+	–	+	–	–	+	+	+	+
Potentilla nivea	+	+	+	+	+	+	–	+	+	+	+
Potentilla ovina	–	–	+	–	+	–	–	+	+	–	+
Potentilla uniflora	+	+	+	–	+	–	–	+	–	+	+
Potentilla villosa	+	–	+	–	+	+	–	+	–	–	+
Sibbaldia procumbens	+	+	+	–	+	+	+	+	+	+	+
LEGUMINOSAE											
Astragalus aboriginum	+	–	+	+	+	–	–	+	–	+	+
Astragalus alpinus	+	+	+	–	+	+	+	+	+	+	+
Astragalus robbinsii	–	–	+	–	+	+	–	+	+	+	+
Astragalus vexilliflexus	+	–	+	+	+	–	–	–	+	+	+
Hedysarum alpinum	+	+	+	+	+	+	–	+	–	+	+
Hedysarum boreale	+	–	+	–	+	–	–	+	–	–	+
Hedysarum mackenzii	+	–	+	+	+	+	+	+	+	+	+
Oxytropis cusickii	–	+	+	–	+	–	–	+	+	+	+
Oxytropis jordalii	–	–	–	–	+	–	–	–	–	–	–
Oxytropis podocarpa	+	–	+	–	+	+	+	+	+	+	–
Oxytropis sericea	+	+	+	–	+	–	+	+	–	+	+
Oxytropis splendens	+	–	+	–	+	–	+	+	+	+	+
ONAGRACEAE											
Epilobium anagallidifolium	+	+	+	–	+	+	+	+	–	+	–
Epilobium angustifolium	+	+	+	+	+	+	+	+	+	+	+
Epilobium clavatum	+	–	+	+	+	+	–	–	–	–	+

	Other Rocky Mountain Areas										
	KW	WW	BJ	RM	WG	SF	GR	KN	PM	BH	WL
Epilobium hornemannii	–	–	+	+	+	–	–	–	+	+	+
Epilobium latifolium	+	+	+	–	+	+	+	+	+	+	+
Epilobium saximontanum	–	–	+	–	+	–	–	–	–	–	–
UMBELLIFERAE											
Heracleum lanatum	+	+	+	+	+	+	+	+	+	+	+
Osmorhiza depauperata	–	+	+	+	+	–	–	+	+	–	+
PYROLACEAE											
Moneses uniflora	+	+	+	+	+	+	+	+	+	+	+
Pyrola asarifolia	+	+	+	+	+	+	+	+	+	+	+
Pyrola elliptica	–	–	+	–	+	–	–	–	–	–	–
Pyrola grandiflora	–	+	+	+	+	–	–	–	–	–	–
Pyrola minor	+	–	+	–	+	–	–	+	+	–	+
Pyrola secunda	+	–	+	+	+	+	+	+	+	+	+
ERICACEAE											
Arctostaphylos rubra	+	+	+	+	+	+	+	–	–	–	–
Arctostaphylos uva-ursi	+	+	+	+	+	+	+	+	+	+	+
Cassiope mertensiana	+	+	+	–	+	+	–	–	–	–	–
Cassiope tetragona	+	+	+	+	+	+	+	+	+	+	–
Kalmia microphylla	+	+	+	–	+	+	–	+	–	+	+
Ledum groenlandicum	+	+	+	+	+	+	–	+	–	+	+
Phyllodoce empetriformis	+	+	+	–	+	+	–	+	–	+	+
Phyllodoce glanduliflora	+	+	+	+	+	+	+	+	+	+	+
Phyllodoce x intermedia	–	–	+	–	+	+	–	–	–	–	+
Rhododendron lapponicum	–	–	+	+	+	–	–	–	–	–	–
Vaccinium vitis-idaea	+	+	+	+	+	+	+	+	–	–	–
PRIMULACEAE											
Androsace chamaejasme	–	+	+	+	+	+	+	+	+	+	+
Androsace septentrionalis	+	+	+	+	+	+	–	+	+	+	+
GENTIANACEAE											
Gentiana prostrata	+	+	+	+	+	+	+	+	+	+	+
Gentianella amarella	–	+	+	+	+	+	–	+	+	+	+
Gentianella propinqua	+	+	+	+	+	+	+	+	+	–	+
POLEMONIACEAE											
Polemonium acutiflorum	+	+	+	–	+	–	–	–	–	–	–
Polemonium viscosum	–	–	–	–	+	–	–	–	–	–	+

	Other Rocky Mountain Areas										
	KW	WW	BJ	RM	WG	SF	GR	KN	PM	BH	WL
HYDROPHYLLACEAE											
Phacelia sericea	+	–	+	+	+	+	+	+	+	+	+
BORAGINACEAE											
Mertensia paniculata	+	+	+	+	+	+	–	+	–	–	–
Mysostis alpestris	+	+	+	+	+	+	+	+	+	+	+
SCROPHULARIACEAE											
Castilleja miniata	+	+	+	+	+	+	+	+	+	+	+
Castilleja occidentalis	+	+	+	+	+	+	+	+	+	+	+
Castilleja rhexifolia	–	–	+	+	+	+	–	+	–	–	+
Euphrasia arctica	–	+	+	+	+	–	–	–	–	–	–
Pedicularis arctica	+	+	+	–	+	+	–	–	–	–	–
Pedicularis bracteosa	+	+	+	+	+	+	+	+	+	+	+
Pedicularis capitata	+	+	+	+	+	–	–	–	–	–	–
Pedicularis flammea	–	–	+	+	+	–	–	–	+	–	–
Pedicularis groenlandica	+	+	+	–	+	+	+	+	+	+	+
Pedicularis lanata	+	+	+	–	–	–	–	–	–	–	–
Rhinanthus minor	+	+	+	+	+	–	+	+	+	–	+
Veronica alpina	+	+	+	+	+	+	+	+	+	+	+
CAPRIFOLIACEAE											
Linnaea borealis	+	+	+	+	+	+	+	+	+	+	+
VALERIANACEAE											
Valeriana dioica	+	+	+	–	+	–	–	+	+	+	+
Valeriana sitchensis	+	+	+	–	+	+	+	+	+	+	+
CAMPANULACEAE											
Campanula lasiocarpa	+	+	+	–	+	+	–	–	–	–	–
Campanula rotundifolia	+	+	+	+	+	+	+	+	+	+	+
Campanula uniflora	–	–	+	+	+	–	–	+	+	+	–
COMPOSITAE											
Achillea millefolium	+	+	+	+	+	+	+	+	+	+	+
Agoseris aurantiaca	+	+	+	–	+	+	+	+	–	+	+
Agoseris glauca	+	–	+	+	+	+	+	+	+	–	+

	Other Rocky Mountain Areas										
	KW	WW	BJ	RM	WG	SF	GR	KN	PM	BH	WL
Antennaria alpina	+	+	+	+	+	+	−	+	−	−	+
Antennaria lanata	+	+	+	+	+	+	+	+	+	+	+
Antennaria monocephala	+	−	+	−	+	−	−	−	−	−	−
Antennaria parvifolia	+	+	+	−	+	−	+	+	+	+	+
Antennaria pulcherrima	+	−	+	−	−	+	−	+	+	+	+
Antennaria umbrinella	+	+	+	+	+	+	−	+	−	+	+
Arnica angustifolia	+	+	+	+	+	+	−	+	+	+	+
Arnica cordifolia	+	+	+	+	+	+	+	+	+	+	+
Arnica diversifolia	−	+	+	−	+	+	−	+	+	−	+
Arnica fulgens	−	−	+	−	+	−	−	−	+	−	+
Arnica latifolia	+	−	+	+	+	+	−	+	+	+	+
Arnica lonchophylla	−	−	+	+	+	−	−	+	+	−	−
Arnica louiseana	−	−	+	+	+	+	−	+	−	−	+
Arnica mollis	−	+	+	−	+	−	+	+	−	+	+
Arnica rydbergii	+	+	+	+	+	+	−	+	−	−	+
Artemisia borealis	+	−	+	−	+	−	−	−	−	+	+
Artemisia norvegica	+	+	+	−	+	−	−	−	+	+	−
Aster alpinus	+	+	+	+	+	+	−	+	+	+	−
Aster sibiricus	+	+	+	+	+	+	−	+	+	+	+
Crepis nana	+	+	+	+	+	+	+	+	+	−	−
Erigeron acris ssp. *debilis*	−	+	+	+	+	+	−	+	+	+	+
Erigeron compositus	+	+	+	+	+	+	+	+	+	+	+
Erigeron grandiflorus	+	+	+	+	+	−	−	+	+	−	−
Erigeron humilis	+	+	+	+	+	+	−	+	+	−	+
Erigeron lanatus	−	−	+	−	+	+	+	+	−	−	+
Erigeron peregrinus	+	+	+	+	+	+	+	+	+	+	+
Erigeron radicatus	−	−	−	+	+	−	−	−	+	−	+
Hieracium triste	+	+	+	+	+	+	−	+	+	+	+
Petasites palmatus	+	+	+	−	+	+	−	−	−	−	+
Petasites vitifolius	−	+	+	−	+	+	+	+	−	−	+
Saussurea nuda	−	+	+	+	+	+	+	+	+	+	−
Senecio canus	−	−	+	+	+	−	−	+	+	+	+
Senecio indecorus	+	−	+	−	+	+	−	−	−	−	+
Senecio lugens	−	−	+	−	+	−	−	+	+	+	+
Senecio pauciflorus	+	+	+	−	+	+	−	+	−	−	−
Senecio triangularis	+	+	+	−	+	+	+	+	+	+	+
Solidago multiradiata	+	+	+	+	+	+	+	+	+	+	+
Solidago spathulata	−	+	+	+	+	−	−	+	+	+	+
Taraxacum ceratophorum	+	+	+	+	+	+	−	+	+	+	+
Taraxacum officinale	−	−	+	+	−	+	−	+	+	+	+
GRAMINEAE											
Agropyron dasystachyum	+	−	+	−	+	−	−	+	−	−	+
Agropyron smithii	−	+	+	−	+	−	−	−	+	−	+
Agropyron violaceum	+	+	+	+	+	+	−	+	+	−	+
Agrostis variabilis	+	−	+	−	+	−	−	−	−	−	−
Bromus pumpellianus	+	+	+	+	+	+	+	+	+	+	+
Calamagrostis canadensis	+	+	+	−	+	+	−	+	−	+	+
Calamagrostis inexpansa	+	−	+	−	+	+	−	−	−	+	+
Calamagrostis purpurascens	+	−	+	+	+	+	+	+	+	+	+
Deschampsia caespitosa	+	+	+	+	+	+	+	+	+	+	+
Elymus innovatus	+	+	+	+	+	+	+	+	+	+	+
Festuca baffinensis	+	−	+	+	+	−	−	+	+	−	−
Festuca brachyphylla	+	+	+	+	+	+	−	+	+	+	+
Festuca saximontana	+	+	+	−	+	+	+	+	+	+	+
Hierochloe alpina	+	+	+	−	+	−	−	−	−	−	−

	Other Rocky Mountain Areas										
	KW	WW	BJ	RM	WG	SF	GR	KN	PM	BH	WL
Phleum commutatum	+	+	+	+	+	+	+	+	+	+	+
Poa alpina	+	+	+	+	+	+	+	+	+	+	+
Poa arctica	+	+	+	–	+	+	–	+	+	–	–
Poa cusickii	+	+	+	–	+	–	–	+	+	+	+
Poa glauca	+	–	+	+	+	–	–	+	+	–	–
Poa juncifolia	–	–	+	–	+	–	–	+	–	–	+
Poa nervosa	–	+	+	–	+	+	–	+	–	+	–
Poa pattersonii	–	–	+	–	+	–	–	+	+	+	+
Poa pratensis	+	–	+	–	+	–	+	+	+	+	+
Trisetum spicatum	+	+	+	+	+	+	+	+	+	+	+
CYPERACEAE											
Carex albo-nigra	+	+	+	+	+	+	–	+	+	+	+
Carex aquatilis	+	+	+	–	+	+	–	+	–	+	+
Carex atrosquama	+	+	+	+	+	+	+	+	+	+	+
Carex capillaris	+	–	+	–	+	+	–	+	–	+	+
Carex franklinii	–	–	+	–	+	–	–	–	–	–	–
Carex gynocrates	–	–	+	–	+	+	–	–	–	+	+
Carex haydeniana	–	–	+	+	+	+	–	+	+	–	+
Carex macloviana	+	–	+	–	+	+	–	+	–	+	+
Carex microptera	–	–	+	–	+	–	–	–	+	–	+
Carex misandra	+	–	+	–	+	–	–	+	–	–	–
Carex nardina	+	+	+	–	+	+	–	+	+	+	+
Carex nigricans	+	+	+	–	+	+	–	+	–	+	+
Carex norvegica	+	+	+	–	+	+	–	+	–	+	+
Carex pachystachya	–	–	+	–	+	–	–	–	–	–	+
Carex paysonis	–	+	+	–	+	–	–	+	–	–	+
Carex petricosa	–	+	+	+	+	–	–	+	–	–	–
Carex phaeocephala	–	+	+	+	+	+	–	+	+	+	+
Carex podocarpa	–	–	+	–	+	–	–	–	–	–	+
Carex raymondii	–	–	+	+	+	–	–	–	–	–	+
Carex rupestris	–	–	+	–	+	+	–	+	+	+	+
Carex saxatilis	+	–	+	–	+	+	–	–	–	–	+
Carex scirpoidea	–	+	+	+	+	+	+	+	+	+	+
Carex spectabilis	+	+	+	–	+	+	–	–	–	–	+
Eriophorum callitrix	–	–	+	–	+	–	–	–	–	–	–
Eriophorum chamissonis	–	–	–	–	+	+	–	+	–	–	+
Eriophorum scheuchzeri	–	+	+	–	+	–	–	+	–	–	–
Kobresia myosuroides	+	–	+	+	+	+	–	+	+	+	+
Kobresia simpliciuscula	–	–	+	–	+	+	–	–	+	–	+
Scirpus caespitosus	+	–	+	–	+	+	–	+	–	–	+
JUNCACEAE											
Juncus albescens	–	+	+	–	+	+	–	+	+	–	+
Juncus balticus	–	–	+	–	+	+	–	+	+	+	+
Juncus castaneus	+	–	+	+	+	+	–	–	–	–	+
Juncus drummondii	+	+	+	–	+	+	–	+	+	+	+
Luzula parviflora	–	+	–	–	+	–	–	+	–	–	+
Luzula piperi	+	+	+	–	+	+	–	+	–	–	+
Luzula spicata	+	+	+	+	+	+	–	+	+	+	+

	Other Rocky Mountain Areas										
	KW	WW	BJ	RM	WG	SF	GR	KN	PM	BH	WL
LILIACEAE											
Streptopus amplexifolius	−	+	+	−	+	−	−	+	−	−	+
Tofieldia pusilla	−	−	+	+	+	+	−	−	−	−	−
Veratrum eschscholtzii	+	+	+	−	−	+	−	+	−	+	+
Zygadenus elegans	+	+	+	+	+	+	+	+	+	+	+
ORCHIDACEAE											
Habenaria viridis	+	−	+	+	+	−	−	+	−	−	+

APPENDIX 2

Nonvascular plants of the Cardinal Divide area. Data from Packer and Vitt (1974), Alberta Ecological Survey (1975), Vitt and Koponen (1976), Horton and Murray (1976), Horton (1982) and Natural Areas Program (1983).

MOSSES

Aulacomnium palustre
Aulacomnium turgidum
Brachythecium salebrosum
Brachythecium turgidum
Bryobrittonia longipes
Bryum pseudotriquetrum
Bryum weigelii
Campylium stellatum
Desmatodon leucostoma
Dicranum acutifolium
Dicranum elongatum
Dicranum fuscescens
Dicranum muehlenbeckii
Dicranum scoparium
Didymodon johansenii
Distichium capillaceum
Ditrichum flexicaule
Drepanocladus revolvens
Drepanocladus uncinatus
Encalypta brevicolla
Encalypta brevipes
Encalypta mutica
Encalypta vulgaris
Grimmia apocarpa
Hylocomium splendens
Hypnum hamulosum
Hypnum procerrimum
Hypnum revolutum
Meesia uliginosa
Orthotrichum pylaisii
Paraleucobryum enerve
Philonotis montana
Pleurozium schreberi
Polytrichum juniperinum
Rhacomitrium canescens
Rhytidium rugosum
Tetraplodon mnioides
Thuidium abietinum
Tomenthypnum nitens
Tortella fragilis
Tortula norvegica
Tortula ruralis

LIVERWORTS

Barbilophozia lycopodioides
Cephaloziella rubella

LICHENS

Alectoria ochroleuca
Bryoria chalybeiformis

Cetraria cucullata
Cetraria ericetorum
Cetraria halei
Cetraria islandica
Cetraria laevigata
Cetraria nivalis
Cetraria pinastri
Cetraria tilesii
Cladonia coccifera
Cladonia pocillum
Cladonia pyxidata
Cornicularia aculeata
Dactylina arctica
Dactylina ramulosa
Hypogymnia oroarctica
Hypogymnia physodes
Lecanora frustulosa
Lecidea decipiens
Lepraria neglecta
Leptogium saturninum
Letharia vulpina
Peltigera aphthosa
Peltigera rufescens
Physconia muscigena
Rhizocarpon geographicum
Solorina saccata
Stereocaulon alpinum
Stereocaulon tomentosum
Thamnolia subuliformis
Thamnolia vermicularis
Xanthoria elegans

APPENDIX 3

Animals of the Cardinal Divide area and occurrence in three other Rocky Mountain areas of Alberta. Areas and sources are: Cardinal Divide area - (Alberta Ecological Survey 1975, Salt 1976a and 1984, author's observations 1974-1984), **BJ** - Banff and Jasper National Parks (Holroyd and Van Tighem 1983), **KN** - Kananaskis (Salt 1976b, Wiseley 1979), **WL** - Waterton Lakes National Park (Nielsen 1973, Sharp 1973). Names are based on American Ornithologists' Union (1982) and Banfield (1974)

	Other Rocky Mountain Areas		
	BJ	KN	WL
BIRDS			
Common Loon	+	+	+
Horned Grebe	+	+	+
Red-necked Grebe	+	+	+
Western Grebe	+	+	+
Great Blue Heron	+	+	+
Canada Goose	+	+	+
Green-winged Teal	+	+	+
Blue-winged Teal	+	+	+
Mallard	+	+	+
American Widgeon	+	+	+
Harlequin Duck	+	+	+
Common Goldeneye	+	+	+
Barrow's Goldeneye	+	+	+
Bufflehead	+	+	+
Wood Duck	-	-	+
Osprey	+	+	+
Bald Eagle	+	+	+
Northern Harrier	+	+	+
Sharpshinned Hawk	+	+	+
Cooper's Hawk	+	+	+
Northern Goshawk	+	+	+
Broad-winged Hawk	+	+	+
Red-tailed Hawk	+	+	+
Roughlegged Hawk	+	+	+
Golden Eagle	+	+	+
American Kestrel	+	+	+
Merlin	+	+	+
Prairie Falcon	+	+	+
Peregrine Falcon	+	+	+
Spruce Grouse	+	+	+
Blue Grouse	+	+	+
White-tailed Ptarmigan	+	+	+
Ruffed Grouse	+	+	+
Sandhill Crane	+	+	-
Killdeer	+	+	+
Greater Yellowlegs	+	+	+
Lesser Yellowlegs	+	+	+
Solitary Sandpiper	+	+	+
Spotted Sandpiper	+	+	+
Common Snipe	+	+	+
Rock Dove	+	+	+
Great Horned Owl	+	+	+
Northern Pygmy Owl	+	+	+
Barred Owl	+	+	-

	Other Rocky Mountain Areas		
	BJ	KN	WL
Boreal Owl	+	+	–
Common Nighthawk	+	+	+
Black Swift	+	+	+
Rufous Hummingbird	+	+	+
Belted Kingfisher	+	+	+
Yellow-bellied Sapsucker	+	+	+
Downy Woodpecker	+	+	+
Hairy Woodpecker	+	+	+
Three-toed Woodpecker	+	+	+
Black-backed Woodpecker	+	+	+
Northern Flicker	+	+	+
Pileated Woodpecker	+	+	+
Olive-sided Flycatcher	+	+	+
Western Wood Peewee	+	+	+
Alder Flycatcher	+	+	+
Least Flycatcher	+	+	+
Hammond's Flycatcher	+	+	+
Dusky Flycatcher	+	+	+
Western Flycatcher	+	+	+
Eastern Kingbird	+	+	+
Say's Phoebe	+	+	+
Horned Lark	+	+	+
Tree Swallow	+	+	+
Violet-green Swallow	+	+	+
Rough-winged Swallow	+	+	+
Cliff Swallow	+	+	+
Barn Swallow	+	+	+
Gray Jay	+	+	+
Blue Jay	+	+	+
Clark's Nutcracker	+	+	+
Black-billed Magpie	+	+	+
American Crow	+	+	+
Common Raven	+	+	+
Black-capped Chickadee	+	+	+
Mountain Chickadee	+	+	+
Boreal Chickadee	+	+	+
Red-breasted Nuthatch	+	+	+
Brown Creeper	+	+	+
Winter Wren	+	+	+
American Dipper	+	+	+
Golden-crowned Kinglet	+	+	+
Ruby-crowned Kinglet	+	+	+
Mountain Bluebird	+	+	+
Townsend's Solitaire	+	+	+
Swainson's Thrush	+	+	+
Hermit Thrush	+	+	+
American Robin	+	+	+
Varied Thrush	+	+	+
Water Pipit	+	+	+
Bohemian Waxwing	+	+	+
Cedar Waxwing	+	+	+
Loggerhead Shrike	–	+	+
European Starling	+	+	+
Warbling Vireo	+	+	+
Red-eyed Vireo	+	+	+
Tennessee Warbler	+	+	+
Orange-crowned Warbler	+	+	+
Yellow Warbler	+	+	+

	Other Rocky Mountain Areas		
	BJ	KN	WL
Yellow-rumped Warbler	+	+	+
Townsend's Warbler	+	+	+
Blackpoll Warbler	+	+	+
Black and White Warbler	+	+	–
American Redstart	+	+	+
Northern Waterthrush	+	+	+
Common Yellowthroat	+	+	+
Wilson's Warbler	+	+	+
Western Tanager	+	+	+
Chipping Sparrow	+	+	+
Savannah Sparrow	+	+	+
Fox Sparrow	+	+	+
Song Sparrow	+	+	+
Lincoln's Sparrow	+	+	+
White-throated Sparrow	+	+	+
White-crowned Sparrow	+	+	+
Golden-crowned Sparrow	+	+	–
Dark-eyed Junco	+	+	+
Brewer's Blackbird	+	+	+
Brown-headed Cowbird	+	+	+
Rosy Finch	+	+	+
Pine Grosbeak	+	+	+
Red Crossbill	+	+	+
White-winged Crossbill	+	+	+
Common Redpoll	+	+	+
Pine Siskin	+	+	+
House Sparrow	+	+	+
MAMMALS			
masked shrew	+	+	+
wandering shrew	+	+	+
water shrew	+	+	+
little brown bat	+	–	+
long-eared bat	+	–	+
long-legged bat	+	–	+
silver-haired bat	+	–	+
big brown bat	+	+	+
hoary bat	+	+	–
American pika	+	+	+
snowshow hare	+	+	+
hoary marmot	+	+	+
woodchuck	–	–	–
Columbian ground squirrel	+	+	+
mantled ground squirrel	+	+	+
least chipmunk	+	+	+
yellow pine chipmunk	+	+	+
red squirrel	+	+	+
northern flying squirrel	+	+	+
beaver	+	+	+
deer mouse	+	+	+
bushy-tailed wood rat	+	+	+
northern bog lemming	+	+	+
Gapper's red-backed vole	+	+	+
heather vole	+	+	+
meadow vole	+	+	+
long-tailed vole	+	+	+
western jumping mouse	+	+	+

	Other Rocky Mountain Areas		
	BJ	KN	WL
porcupine	+	+	+
coyote	+	+	+
wolf	+	+	+
black bear	+	+	+
grizzly bear	+	+	+
marten	+	+	+
fisher	+	+	+
short-tailed weasel	+	+	+
long-tailed weasel	+	-	+
mink	+	+	+
wolverine	+	+	+
cougar	+	+	+
lynx	+	+	+
mule deer	+	+	+
white-tailed deer	+	+	+
American moose	+	+	+
wapiti	+	+	+
mountain goat	+	+	+
bighorn sheep	+	+	+

LITERATURE CITED

Achuff, P.L. 1982. Appendix A: Plant Checklists. *In* W.D. Holland and G.M. Coen (gen. eds.), Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume II: Soil and vegetation resources. Alberta Institute of Pedology Publication SS-82-44: 515-530.

Achuff, P.L. and G.M. Coen. 1980. Subalpine Cryosolic soils in Banff and Jasper National Parks. Canadian Journal of Soil Science 60: 579-581.

Achuff, P.L. and I.G.W. Corns. 1982. Vegetation. *In* W.D. Holland and G.M. Coen (gen. eds.), Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume II: Soil and vegetation resources. Alberta Institute of Pedology Publication SS-82-44: 71-156.

Achuff, P.L. and I.G.W. Corns. 1984. Plants new to Alberta from Banff and Jasper National Parks. Canadian Field-Naturalist (in press).

Alberta Ecological Survey. 1975. Checksheet for Survey of Natural Areas - Mountain Park. File report, Department of Botany, University of Alberta, Edmonton. 12 pp.

Alberta Ecological Survey. 1976. Checksheet for Survey of Natural Areas - Willmore Wilderness Park. File report, Department of Botany, University of Alberta, Edmonton. 22 pp.

Alley, N.F. 1973. Glacial stratigraphy and the limits of the Rocky Mountain and Laurentide ice sheets in southwestern Alberta, Canada. Bulletin of Canadian Petroleum Geology 21: 153-177.

American Ornithologists' Union. 1982. Thirty-fourth Supplement to the American Ornithologists' Union Check-list of North American Birds. Auk 99: 16 pp.

Anderson, H. 1978. Biophysical analysis and evaluation of capability - Castle River. Alberta Energy and Natural Resources, Edmonton, ENR Report 64: 72 pp.

Anderson, H.G. 1979. Ecological land classification and evaluation - Highwood-Sheep. Alberta Energy and Natural Resources, Edmonton, ENR Report 93: 63 pp.

Bamberg, S.A. and J. Major. 1968. Ecology of the vegetation and soils associated with calcareous parent materials in three alpine regions of Montana. Ecological Monographs 38: 127-168.

Banfield, A.W.F. 1974. The mammals of Canada. University of Toronto Press, Toronto, Ontario. 438 pp.

Bayrock, L.A. 1969. Incomplete continental glaciation record in Alberta, Canada. *In* H.E. Wright, Jr. (ed.), Quaternary geology and climate. Proceedings of the VII Congress of the International Association for Quaternary Research 16: 99-103.

Belicek, J. 1976. Coccinellidae of western Canada and Alaska. MSc thesis, University of Alberta, Edmonton. 408 pp.

Brathay Exploration Group. 1981. Flora of the Ghost River Wilderness Area. Report to Provincial Parks Division, Alberta Parks and Recreation, Edmonton. 30 pp.

Bryant, J.P. and E. Scheinberg. 1970. Vegetation and frost activity in an alpine fellfield on the summit of Plateau Mountain, Alberta. Canadian Journal of Botany 48: 751-771.

Canada Soil Survey Committee. 1978. The Canadian system of soil classification. Agriculture Canada Publication 1646: 164 pp.

Clifford, H.F. and G. Bergstrom. 1976. The blind aquatic isopod *Salmasellus* from a cave spring in the Rocky Mountains' eastern slopes, with comments on a Wisconsin refugium. Canadian Journal of Zoology 54: 2028-2032.

Coen, G.M. and W.D. Holland. 1976. Soils of Waterton Lakes National Park, Alberta. Alberta Institute of Pedology Report S-73-33: 116 pp.

Crack, S.N. 1977. Flora and vegetation of Wilcox Pass, Jasper National Park. MSc thesis, University of Calgary, Calgary, Alberta. 284 pp.

Crockett, K.J. 1981. Drummond Creek rock glacier reconnaissance report. File report, Natural Areas Program, Alberta Energy and Natural Resources, Edmonton. 8 pp.

Daborn, G.R. 1976. Occurrence of an arctic fairy shrimp *Polyartemiella hazeni* (Murdoch) 1884 (Crustacea: Anostraca) in Alberta and Yukon Territory. Canadian Journal of Zoology 54: 2026-2028.

Denford, K.E. and I. Karas. 1975. A study of the flavonoids of certain species of *Cassiope* (Ericaceae). Canadian Journal of Botany 53: 1192-1195.

Drury, W.H. and R.C. Rollins. 1952. The North American representatives of *Smelowskia calycina* (Cruciferae). Rhodora 54: 85-119.

Dumanski, J., T.M. Macyk, C.F. Veauvy and J.D. Lindsay. 1972. Soil and land evaluation of the Edson-Hinton area, Alberta. Alberta Soil Survey Report 31: 119 pp.

Dumanski, J., S. Pawluk, C.G. Vucetich and J.D. Lindsay. 1980. Pedogenesis and tephrochronology of loess derived soils, Hinton, Alberta. Canadian Journal of Earth Sciences 17: 52-59.

Elisens, W. 1978. Contributions to the taxonomy of *Oxytropis campestris* (L.) DC (Leguminosae) in northwestern North America. MSc thesis, University of Alberta, Edmonton. 197 pp.

Environment Canada. 1975a. Canadian normals, 1941-1970. vol. 1-SI. Temperature. Atmospheric Environment Service, Downsview, Ontario. 198 pp.

Environment Canada. 1975b. Canadian normals, 1941-1970. vol. 2-SI. Precipitation. Atmospheric Environment Service, Downsview, Ontario. 333 pp.

Environment Canada. 1982a. Canadian climate normals, 1951-1980. vol. 2. Temperature. Atmospheric Environment Service, Downsview, Ontario. 305 pp.

Environment Canada. 1982b. Canadian climate normals, 1951-1980. vol. 3. Precipitation. Atmospheric Environment Service, Downsview, Ontario. 602 pp.

Environment Canada. 1982c. Canadian climate normals, 1951-1980. vol. 4. Degree Days. Atmospheric Environment Service, Downsview, Ontario. 280 pp.

Ferguson, N.B. 1980. Physical land classification of the Kakwa-Willmore Regional Recreational Plan Study Area. Alberta Energy and Natural Resources, Edmonton, Technical Report T/12-5: 57 pp.

Glover, B.W. 1979. Late Quaternary river terrace evolution in part of the Athabasca River valley. MSc thesis, University of Alberta, Edmonton. 239 pp.

Greene, C.W. 1974. The taxonomy of *Smelowskia calycina* (Stephan) C.A. Meyer (Cruciferae) in North America. MSc thesis, University of Alberta, Edmonton. 109 pp.

Griffiths, G.C.D. 1981. Vegetation survey and mapping of the Beehive Candidate Ecological Reserve. Report to Natural Areas Program, Alberta Energy and Natural Resources, Edmonton. 100 pp.

Griffiths, G.C.D. 1982. Vegetation survey and mapping of the Plateau Mountain Candidate Ecological Reserve. Report to Natural Areas Program, Alberta Energy and Natural Resources, Edmonton. 88 pp.

Holland, W.D. and G.M. Coen. (gen. eds.) 1982. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume II: Soil and vegetation resources. Alberta Institute of Pedology Publication SS-82-44: 540 pp.

Holroyd, G.L. and K.J. Van Tighem. 1983. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume III: The wildlife inventory. Canadian Wildlife Service report to Parks Canada, Calgary. 444 pp.

Holter, M.E. and I.J. McLaws. 1977. Geology of Alberta Rocky Mountains and foothills. Open file report, Alberta Research Council, Edmonton.

Holter, M.E. and G.B. Mellon. 1972. Geology of the Luscar (Blairmore) coal beds, central Alberta foothills. *In* Proceedings of the First Geological Conference on Western Canadian Coal. Alberta Research Council Report 9C588: 125-135.

Horton, D.G. 1979. Encalyptaceae Americanae Exsiccatae: an annotated guide to fasciculus 1 (numbers 1-10). Bryologist 82: 450-468.

Horton, D.G. 1982. The status and significance, relative to refugial theory, of bryofloristic research in western Canada. Nova Hedwigia 71: 435-449.

Horton, D.G. and B.M. Murray. 1976. *Encalypta brevipes* and *E. mutica*, gymnostomous species new to North America. Bryologist 79: 321-331.

Irish, E.J.W. 1965. Geology of the Rocky Mountain Foothills, Alberta. Geological Survey of Canada Memoir 334: 122 pp.

Jackson, L.E. Jr. 1977. Quaternary stratigraphy and terrain inventory of the Alberta portion of the Kananaskis Lakes 1:250,000 sheet (82-J). PhD thesis, University of Calgary, Calgary, Alberta. 480 pp.

Jacques, D.R. 1978. Investigations into the capabilities of computer-assisted LANDSAT imagery for reconnaissance surveys of ecosystems in the Rocky Mountains of Alberta, 1977. Environmental Sciences Center (Kananaskis), University of Calgary, Calgary, Alberta. 249 pp.

Jacques, D.R. and A.H. Legge. 1974. Living Environment: Vegetation. *In* The Mountain Environment and Urban Society, Kananaskis Pilot Study, Environmental Sciences Center, University of Calgary, Calgary, Alberta. pp. 193-280.

Johnson, J.D. 1975. An evaluation of the summer range of bighorn sheep (*Ovis canadensis canadensis* Shaw) on Ram Mountain, Alberta. MSc thesis, University of Calgary, Calgary, Alberta.

Karpuk, E.W. and A.G. Levisohn. 1980. Physical land classification of the Livingstone-Porcupine study area. Alberta Energy and Natural Resources, Edmonton, ENR Report 127.

Kilby, W.E. 1978. Structural geology and stratigraphy of the coal-bearing and adjacent strata near Mountain Park, Alberta. MSc thesis, University of Alberta, Edmonton. 154 pp.

Koeppen, W. 1931. Grundriss der Klimakunde. Springer Verlag, Berlin.

Kondla, N. 1978. An overview vegetation survey of Kananaskis Provincial Park. Alberta Recreation, Parks and Wildlife, Edmonton. 123 pp.

Kuchar, P. 1973. Habitat types of Waterton Lakes National Park. Report to Parks Canada, Calgary. 301 pp.

Kuijt, J. 1982. A flora of Waterton Lakes National Park. University of Alberta Press, Edmonton. 684 pp.

La Roi, G.H. and R.A. Ellis. 1984. The flora and vegetation around fire lookout towers and their access roads in western Alberta. Report to Alberta Forest Development Research Trust, Alberta Energy and Natural Resources, Edmonton. 346 pp.

Lee, P., L. Allen and P. McIsaac. 1982. Vegetation and flora of the alpine and upper subalpine zones - White Goat and Siffleur Wilderness Areas. File report, Natural Areas Program, Alberta Energy and Natural Resources, Edmonton. 101 pp.

Longley, R.W. 1967. Climate and weather patterns. *In* W.G. Hardy (ed.), Alberta, a natural history. M.G. Hurtig, Edmonton, pp. 53-67.

Luckman, B.H. and K.J. Crockett. 1978. Distribution and characteristics of rock glaciers in the southern part of Jasper National Park, Alberta. Canadian Journal of Earth Sciences 15: 540-550.

MacKay, B.R. 1929. Mountain Park sheet. Geological Survey of Canada Map 208A.

Mellon, G.B. 1966. Lower Cretaceous section, Cadomin area, Alberta. *In* G.B. Williams (ed.), Guide book, 8th Annual Field Trip, Cadomin, Alberta. Edmonton Geological Society. pp. 67-69.

McGregor, C.A. 1979. Ecological land classification and evaluation - Ghost River study area. Alberta Energy and Natural Resources, Edmonton, ENR Report 116: 64 pp.

Mortimer, P.R. 1978. The alpine vascular flora and vegetation of Prospect Mountain, Front Range, Rocky Mountains, Alberta. MSc thesis, University of Alberta, Edmonton. 238 pp.

Mountjoy, E.W. 1961. Rocky Mountain Front Ranges along the Athabasca Valley, Jasper National Park. *In* Guide book, 3rd Annual Field Trip, Jasper. Edmonton Geological Society. pp. 14-42.

Mountjoy, E.W. 1962. Mount Robson (southeast) map area, Rocky Mountains of Alberta and British Columbia (83E SE). Geological Survey of Canada Paper 61-31: 114 pp.

Myers, S. and J. Rintoul. 1983. Cardinal River Divide ungulate aerial survey. File report, Alberta Energy and Natural Resources. 15 pp.

Natural Areas Program. 1980-1982. Checksheets and field notes for Cardinal Divide area. File report, Alberta Energy and Natural Resources, Edmonton.

Natural Areas Program. 1981a. Checksheet for Moose Mountain. File report, Alberta Energy and Natural Resources, Edmonton. 10 pp.

Natural Areas Program. 1981b. Checksheet for Mount Buller. File report, Alberta Energy and Natural Resources, Edmonton. 6 pp.

Natural Areas Program. 1981c. Checksheet for Marmot/Wind Creek basins. File report, Alberta Energy and Natural Resources, Edmonton. 12 pp.

Natural Areas Program. 1981d. Checksheet for Upper Evans Thomas. File report, Alberta Energy and Natural Resources, Edmonton. 23 pp.

Natural Areas Program. 1981e. Checksheet for Elbow-Sheep Divide. File report, Alberta Energy and Natural Resources, Edmonton. 14 pp.

Natural Areas Program. 1983. Flora of the Cardinal Divide Proposed Ecological Reserve. File report, Alberta Energy and Natural Resources, Edmonton. 35 pp.

Nielsen, P.L. 1973. The mammals of Waterton Lakes National Park, Alberta. Canadian Wildlife Service report to National and Historic Parks Branch, Calgary. 176 pp.

Ogilvie, R.T. 1962. Notes on plant distribution in the Rocky Mountains of Alberta. Canadian Journal of Botany 40: 1091-1094.

Packer, J.G. 1983. Flora of Alberta. Second edition. University of Toronto Press, Toronto. 687 pp.

Packer, J.G. and C.E. Bradley. 1984. A checklist of the rare vascular plants in Alberta. Provincial Museum of Alberta, Natural History Occasional Paper 5: 112 pp.

Packer, J.G. and K.E. Denford. 1974. A contribution to the taxonomy of *Arctostaphylos uva-ursi*. Canadian Journal of Botany 52: 743-753.

Packer, J.G. and M.G. Dumais. 1972. Additions to the flora of Alberta. Canadian Field-Naturalist 86: 269-274.

Packer, J.G. and D.H. Vitt. 1974. Mountain Park: a plant refugium in the Canadian Rocky Mountains. Canadian Journal of Botany 52: 1391-1409.

Parks Canada. 1984. A planning scenario for the Four Mountain Parks Block. Western Regional Office, Calgary, Alberta. 81 pp.

Pettapiece, W.W., P.L. Achuff, K. Leggat and W.L. Strong. 1980. Ecoregions of Alberta. Report to Ecoregions Working Group, Canadian Committee on Ecological (Biophysical) Land Classification, Environment Canada, Lands Directorate, Ottawa, Ontario. 65 pp.

Pike, E.M. 1978. Origin of tundra butterflies in Alberta, Canada and their significance in the study of refugia of Wisconsin age. MSc thesis, University of Alberta. 137 pp.

Powell, J.M. 1978. Climatic classifications of the prairie provinces of Canada. *In* K.D. Hage and E.R. Reinelt (eds.), Essays on Meteorology and Climatology in honour of Richmond W. Longley, Department of Geography, University of Alberta, Edmonton, pp. 211-229.

Price, R.A. 1962. Fernie map area, east half, Alberta and British Columbia. Geological Survey of Canada Paper 62-24.

Price, R.A. and E.W. Mountjoy. 1970. Geologic structure of the Canadian Rocky Mountains between the Bow and Athabasca Rivers - a progress report. Geological Survey of Canada Special Paper 6: 25 pp.

Reeves, B.O.K. 1973. The nature and age of the contact between Laurentide and Cordilleran ice sheets in the western interior of North America. Arctic and Alpine Research 5: 1-16.

Reimchen, T.H.F. and L.A. Bayrock. 1977. Surficial geology and erosion potential, Rocky Mountains and foothills Alberta. Alberta Research Council, open file report 77-14.

Reinelt, E.R. 1967. The effect of topography on the precipitation regime of Waterton Lakes National Park. Albertan Geographer 4: 19-30.

Reinelt, E.R. 1970. On the role of orography in the precipitation regime of Alberta. Albertan Geographer 6: 45-58.

Roed, M.A. 1968. Surficial geology of the Edson-Hinton area, Alberta. PhD thesis, University of Alberta, Edmonton. 200 pp.

Russell, W.B. 1980. The vascular flora and natural revegetation of abandoned coal mined land, Rocky Mountain foothills, Alberta. MSc thesis, University of Alberta, Edmonton. 96 pp.

Rutter, N.W. 1978. Geology of the ice-free corrider. Abstracts of the Fifth Biennial Meeting of the American Quaternary Association, pp. 2-12.

Salt, J.R. 1976a. Résumé of a preliminary zoological study of the Cardinal/McLeod Divide. Correspondence on file, Natural Areas Program, Alberta Energy and Natural Resources.

Salt, J.R. 1976b. Terrestrial vertebrate fauna of Kananaskis Provincial Park area. Peregrine Research and Documentation Ltd., Edmonton, Alberta. 405 pp.

Salt, J.R. 1984. Checklist of the birds and mammals of the upper Cardinal River/Cadomin region. Manuscript. 7 pp.

See, M.G. and L.C. Bliss. 1980. Alpine lichen-dominated communities in Alberta and the Yukon. Canadian Journal of Botany 58: 2148-2170.

Sharp, P.L. 1973. Birds of Waterton Lakes National Park. Canadian Wildlife Service report to National and Historic Parks Branch, Calgary. 347 pp.

Stalker, A.M. and J.E. Harrison. 1977. Quaternary glaciation of the Waterton-Castle River region of Alberta. Bulletin of Canadian Petroleum Geology 25: 882-906.

Stott, D.F. 1963. Cretaceous Alberta Group and equivalent rocks, Rocky Mountain Foothills, Alberta. Geological Survey of Canada Memoir 317.

Stringer, P.W. 1973. An ecological study of grasslands of Banff, Jasper and Waterton Lakes National Parks. Canadian Journal of Botany 51: 383-411.

Strong, W.L. 1979. Ecological land classification and evaluation - Livingstone-Porcupine. Alberta Energy and Natural Resources, Edmonton, ENR Report 94: 89 pp.

Thornethwaite, C.W. and J.R. Mather. 1957. Instructions and tables for computing potential evapotranspiration and the water balance. Drexel Institute, Technical Publications in Climatology 10: 185-311.

Trottier, G.C. 1972. Ecology of the alpine vegetation of Highwood Pass, Alberta. MSc thesis, University of Calgary, Calgary, Alberta. 229 pp.

Twardy, A.G. and I.G.W. Corns. 1980. Soil survey and interpretations of the Wapiti map area, Alberta. Alberta Institute of Pedology Bulletin 39: 139 pp.

Vitt, D.H. and T. Koponen. 1976. Mosses of the Grande Cache Region of Alberta, Canada. Lindbergia 3: 277-286.

Washburn, A.L. 1973. Periglacial processes and environments. Edward Arnold (Publishers) Ltd., London, 320 pp.

Williams, G.D. and L.A. Bayrock. 1966. Surficial geology between Edmonton and Cadomin near Highways 16 and 47. *In* G.D. Williams (ed.), Guide book, 8th Annual Field Trip, Cadomin. Edmonton Geological Society. pp. 105-134.

Wiseley, A.N. 1979. A review of birds and their habitats in Kananaskis Country. Alberta Energy and Natural Resources, Fish and Wildlife Division, Planning Document #2: 157 pp.

Wolf, S.J., J.G. Packer and K.E. Denford. 1979. The taxonomy of *Minuartia rossii* (Caryophyllaceae). Canadian Journal of Botany 57: 1673-1686.